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GASOLENE MOTOR CAR; UNION PACIFIC RY.

The Union Pacific Ry. has for some months been experimenting with railway motor cars intended for branch line and auxiliary passenger service, the cars being operated by gasolene engines and built at the company's shops at Omaha, Neb., to the designs and patents of Mr. W. R. McKeen, Jr., Superintendent of Motive Power and Machinery. The first car, described and illustrated in our issue of April 6, 1905, was 31 ft. long, weighing about 20 tons, and mounted on two axles with 42-in. wheels and a wheelbase of 16 ft. 6 ins. This car has made more mileage than probably any other railway motor car, having been sent on exhibition trips all over the country, and the results have been so satisfactory as to lead to the construction of a second and larger car, which has recently been completed. This second car has an engine of 100 HP. (as had the first car), but a third car with an engine of 200 HP. is under construction; this is 55 ft. long, with a mail compartment and a seating capacity of 41 passengers, and is intended to haul a combination baggage and freight car 32 ft. long, having rounded ends. All the engines have been built by the Standard Motor Construction Co., of Jersey City, N. J.

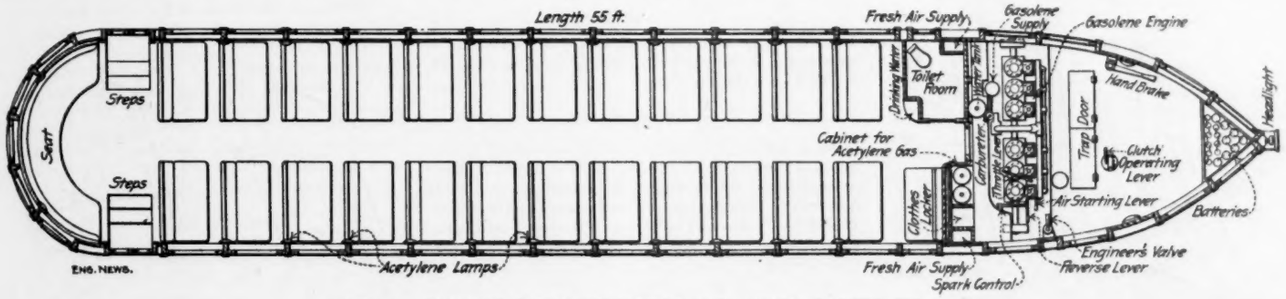

FIG. 1. PLAN OF GASOLENE MOTOR CAR; UNION PACIFIC RY.

The second car, which has been recently turned out of the shops, is shown in Fig. 2, while a plan is given in Fig. 1. It is 56 ft. in length, with a pointed front end or "wind splitter" and a rounded rear end, which is believed to cause less eddying air currents (and consequently less dust) than the usual square end. The side entrances are at the rear of the car, and the engines and mechanism are in the pointed end; the roof is rounded, or of the "turtle-back" pattern, depressed at front and rear. The car is lighted by 25 acetylene lamps, placed behind disks or panels in the upper part of the sides, thus giving a diffused light. It has Cottier exhaust ventilators in the top of the turtle-back roof, while fresh air from an inlet at the top of the car, near the front, is distributed at various points. In winter this air supply will be heated by being passed over the circulating coils for cooling the water from the cylinder jackets. These coils are housed behind the pilot. The floor is watertight and the car has other arrangements to allow of sanitary methods of cleaning. The inside finish is of mahogany, with white headlining, and the seats are upholstered in leather.

FIG. 2. GASOLENE MOTOR CAR; UNION PACIFIC RY.
W. R. McKeen, Jr., Superintendent of Motive Power and Machinery.

One of the special features of the car is that it is built entirely of steel, the underframing and side and roof framing being of steel shapes, while the sides are of steel plate. The car is mounted on a pair of four-wheel trucks, having steel frames and rolled steel wheels. The front truck has a pair of 42-in. driving wheels and a pair of 34-in. wheels. The rear truck has 34-in. wheels. The total weight of the car is 56,000 lbs., but it is expected that the similar car now being built will weigh only about 50,000 lbs. The engine is of 100 HP., of the marine type, with six vertical inverted cylinders, and is placed transversely of the car. It was specially designed for the service, and has suction inlet valves, mechanically operated exhaust valves, and a "make and break" spark ignition, with a primary battery for use in starting and a magneto apparatus for use when running. The engine runs at speeds of 150 to 600 revolutions per minute, its economical speed being 400 revolutions. It drives the front axle of the leading truck, power being transmitted to the axle by means of a special design of friction clutch, in combination and differentiating with a special design of "octoroon" clutch. Both clutches operate in unison by means of an operating valve in connection with air cylinders. The gearing is arranged for two speeds, and the car has attained a maximum speed of 63 miles per hour. The engine is started, connected to the high or low speed gears, or disconnected altogether by means of the clutches, which are operated by compressed air and controlled by a simple operating valve. In starting, compressed air from storage tanks is admitted to three of the cylinders, and the engine is not connected up until it is working at full power. In making station stops, the engine is not stopped but simply disconnected. The car is fitted with special air and hand brakes.

The principal dimensions of the car are as follows:

Length	56 ft. 8 ins.
Width	9 ft. 8 ins.
Height, rail to floor	4 ft. 3¾ ins.
Height, rail to top of roof	12 ft. 11⁹/₁₆ ins.
Wheelbase, front (driving) truck	9 ft. 8 ins.
Wheelbase, rear truck	7 ft. 0 ins.
Wheelbase, total	37 ft. 8 ins.
Engine, 100 HP.; six cylinders	6 × 8 ins.
Gasoline tank, capacity	100 gallons
No. of passengers	57
Weight	56,000 lbs.

A NEW FORM OF PROCEDURE FOR EARTHWORK COMPUTATIONS, AND A SLIDE RULE THEREFOR.

By C. W. Crockett.*

1. It may be demonstrated that the prismoidal formula will give the correct volume of any solid which satisfies the following conditions:

(a) Both ends shall be wholly in excavation, or both wholly in embankment.

(b) The ends shall be in parallel planes. The end section may be a point, a line, or any polygon bounded by straight lines.

(c) The longitudinal edges shall be straight lines joining the vertices of the two ends.

(d) Each longitudinal face shall be generated by a straight line moving along the two bounding longitudinal edges, and always parallel to the planes of the ends. Hence the faces are either plane surfaces or warped surfaces—that is, portions of hyperbolic paraboloids.

Such a solid is shown in Fig. 1, a somewhat complicated example, and yet one that may occur during construction. A B C D E — A′ C′ D′ E′ is the original surface of the ground, and A H G F E — A′ G′ F′ E′ the surface after excavation has been made.

2. In the formula for the volume, in cubic yards, of the solid in Fig. 1, there will be two terms for each longitudinal edge, C C′, for example, and each one of these terms will be the product of

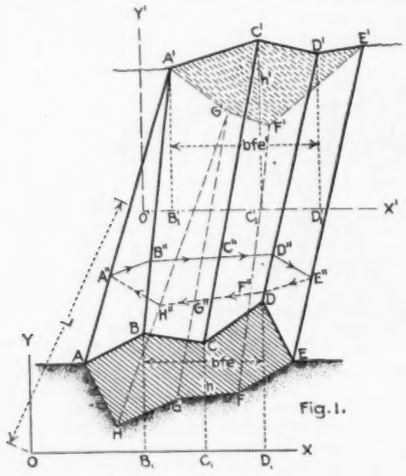

Fig. 1.

A Prismoid in Excavation.

three factors divided by 324. These terms may be written as follows:

If we place a pencil point at A″, on the edge A A′, and then move the pencil clockwise around the solid, as shown by the arrow heads, it will come in succession to the edges A A′, B A′, C C′, D D′, and so on; of any three consecutive edges (say B A′, C C′ and D D′), one (C C′) is the middle edge, one (D D′) is the forward edge, and one (B A′) is the back edge. Let h and h′ be the heights, above the horizontal datum lines O X and O′ X′ respectively, at the ends of any edge (C C′); let b f e and b f e′ be the horizontal distances between the back and forward edges (in the end sections), negative when the end of the forward edge is to the left of the corresponding end of the back edge; and let L be the perpendicular distance between the two end planes. Then the two terms, in the formula for the volume, that involve h and h′ are

$$\tfrac{1}{324}\,L\,(2\,h + h')\,b\,f\,e \quad \text{and} \quad \tfrac{1}{324}\,L\,(2\,h' + h)\,b\,f\,e'.$$

These terms may be written by the following rule, which may be called

General Rule for Prismoidal Volumes—*For each longitudinal edge:—At each end, to twice the height at that end add the height at the other end, and multiply the sum by the horizontal distance between the back and forward edges at the first end (negative when that end of the forward edge is to the left of the corresponding end of the back edge), and by the length of the solid divided by 324.*

The solid in Fig. 1 has 8 longitudinal edges, so that there are 16 terms in all, some of which will be negative, and their algebraic sum will give the volume of the solid.

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EXAMPLE.—Writing the horizontal distances from O Y (or O′ Y′) to the several points in the numerators, and their heights above O X (or O′ X′) in the denominators, let the dimensions for Fig. 1, with a length, L, of 60 feet, be written thus:

A′	C′	D′	E′	F′	G′	A′
10 / +50	40 / +60	58 / +52	74 / +55	45 / +30	30 / +35	10 / +50

20 / +30	40 / +40	60 / +34	80 / +50	90 / +35	70 / +20	50 / +18	30 / +10	20 / +30	40 / +40
A	B	C	D	E	F	G	H	A	B

the inclined lines indicating the longitudinal surface edges. The two lines marked with a cross are duplicates of others, and are inserted only for convenience in forming the terms. Then the terms, in the formula for volume, corresponding to each edge are found as follows:

The factor $\frac{1}{324}$ L, or $\frac{1}{324} \times 60$, is constant for the solid.

Place a pencil point on the line B A′ (in the notes); then, starting with the end B, twice the height at that end plus the height at the other end $= 2 \times 40 + 50 = 130$; the forward edge is C C′ and the back edge is A A′, so that b f e is the horizontal distance from A to C $= 60 - 20 = 40$; hence the term is

$$\frac{1}{324} \times 60 \times 130 \times 40.$$

At the end A′, twice the height at that end + the height at the other end $= 2 \times 50 + 40 = 140$; b f e at this end is the distance from A′ to C′ $= 40 - 10 = 30$; hence the term is

$$\frac{1}{324} \times 60 \times 140 \times 30.$$

As another illustration, place the pencil point on G G′; starting at the end G, twice the height at that end + the height at the other end $= 2 \times 18 + 35 = 71$; b f e at this end is the distance between F and H $= 70 - 30 = 40$, which should be given the negative sign since H is to the left of F; hence the term is

$$\frac{1}{324} \times 60 \times 71 \times (-40).$$

At the end G′, twice the height + the height at the other end $= 2 \times 35 + 18 = 88$; b f e at this end is the distance between F′ and G′ (since the adjacent edges are F F′ and H G′) $= 45 - 30 = 15$, which should be negative since G′ is to the left of F′; hence the term is

$$\frac{1}{324} \times 60 \times 88 \times (-15).$$

The other terms are found in a similar manner, with the following results:

Edge.	Terms.	+ Vols.	— Vols.
B A′	$\frac{1}{324}$. 60 . 130 . 40	962 26/27	
"	" " 140 . 30*	777 7/9	
C C′	" " 128 . 40	948 4/27	
"	" " 154 . 48	1,368 8/9	
D D′	" " 152 . 30	844 4/9	
"	" " 154 . 34	969 17/27	
E E′	" " 125 . (— 10)†		231 13/27
"	" " 145 . (— 13)†		349 2/27
F F′	" " 70 . (— 40)†		518 14/27
"	" " 80 . (— 44)†		651 23/27
G G′	" " 71 . (— 40)†		525 25/27
"	" " 88 . (— 15)‡		244 12/27
H G′	" " 55 . (— 30)†		305 15/27
"	" " 80 . (— 20)†		296 8/27
A A′	" " 110 . 10	203 19/27	
"	" " 130 . (— 20)†		481 13/27
		6,075 15/27	3,604 17/27
		3,604 17/27	
		2,470 25/27 cu. yds.	

* The back edge is A A′ so that b f e′ = 40 — 10.

† The end of the forward edge is to the left of the corresponding end of the back edge.

‡ The forward edge is H G′ so that b f e′ = 30 — 45.

3. The following proof of one of the cases to which the prismoidal formula is applicable will serve to indicate the process that led to the statement of the general rule.

It may be shown, by the use of geometry and calculus, that the prismoidal formula will give the correct volume of any solid satisfying the following conditions (Fig. 2):

(a) The base A A′ B′ B shall be a horizontal plane.

(b) The sides A A′ C′ C and B B′ D′ D shall be vertical planes.

(c) The ends A B D C and A′ B′ D′ C′ shall be parallel vertical planes.

(d) The top C D D′ C′ shall be generated by a straight line moving along the lines C C′ and D D′ and always parallel to the end planes.

Using the notation shown in Fig. 2, the areas of the trapezoidal ends are $\frac{1}{2}$ m $(h_1 + h_2)$ and $\frac{1}{2}$ m′ $(h_1' + h_2')$ respectively. The base of the midsection is $\frac{1}{2}$ $(m + m')$ and its parallel sides are $\frac{1}{2}$ $(h_1 + h_1')$ and $\frac{1}{2}$ $(h_2 + h_2')$, so that its area is

$$\frac{1}{2}\,\frac{m + m'}{2}\left(\frac{h_1 + h_1'}{2} + \frac{h_2 + h_2'}{2}\right)$$

or

$$\frac{1}{8}\,(m + m')(h_1 + h_1' + h_2 + h_2').$$

Hence, if L is the perpendicular distance between the two ends, we find that the volume, according to the prismoidal formula, after dividing by 27 to reduce it to cubic yards, is

$$V = \frac{1}{27} \cdot \frac{1}{6}\,L\left[\frac{1}{2}\,m\,(h_1 + h_2) + \frac{1}{2}\,m'\,(h_1' + h_2') + \frac{1}{2}\,(m + m')(h_1 + h_1' + h_2 + h_2')\right]$$

which may be written

$$V = \frac{1}{324}\,L\left[(2\,h_1 + h_1')\,m + (2\,h_1' + h_1)\,m'\right] + \frac{1}{324}\,L\left[(2\,h_2 + h_2')\,m + (2\,h_2' + h_2)\,m'\right] \quad \ldots\ldots(1)$$

In Fig. 2, the end section A B D C becomes a line when m = 0, and it becomes a point when m = 0 and $h_1 = h_2 = 0$, but in every case Eq. (1) will give the correct volume.

When, as in Fig. 3, the solid is formed of two solids, each of which satisfies the conditions stated in Section 3, the ends A B C c b a and A′ B′ C′ c′ b′ a′ being in parallel planes, the volume may

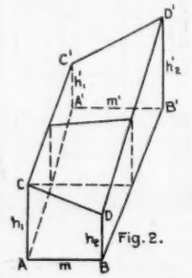


Fig. 2.

The Truncated Right Prism — the Simplest Prismoid.

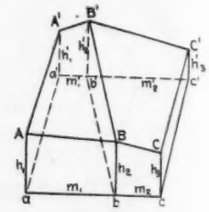


Fig. 3.

A More Complex Prismoid: Two Truncated Right Prisms in Conjunction.

be found by applying Eq. (1) to the two solids separately and adding the results. Hence

$$V = \frac{1}{324}\,L\left[(2\,h_1 + h_1')\,m_1 + (2\,h_1' + h_1)\,m_1'\right] + \frac{1}{324}\,L\left[(2\,h_2 + h_2')\,m_1 + (2\,h_2' + h_2)\,m_1'\right] + \frac{1}{324}\,L\left[(2\,h_2 + h_2')\,m_2 + (2\,h_2' + h_2)\,m_2'\right] + \frac{1}{324}\,L\left[(2\,h_3 + h_3')\,m_2 + (2\,h_3' + h_3)\,m_2'\right] = \frac{1}{324}\,L\left[(2\,h_1 + h_1')\,m_1 + (2\,h_1' + h_1)\,m_1'\right] + \frac{1}{324}\,L\left[(2\,h_2 + h_2')\,(m_1 + m_2) + (2\,h_2' + h_2)\,(m_1' + m_2')\right] + \frac{1}{324}\,L\left[(2\,h_3 + h_3')\,m_2 + (2\,h_3' + h_3)\,m_2'\right]$$

so that the two terms containing the heights h_2 and h_2' at the ends of the middle longitudinal surface edge are

$$\frac{1}{324}\,L\,(2\,h_2 + h_2')\,(m_1 + m_2)$$

and

$$\frac{1}{324}\,L\,(2\,h_2' + h_2)\,(m_1' + m_2') \quad \ldots\ldots(2)$$

These terms may be written as follows: At each end of the edge, to twice the height at that end add the height at the other end, and multiply the sum by the horizontal distance, at the first end, between the adjacent longitudinal edges, and by

$$\frac{1}{324}\,L.$$

In the General Rule the convention with reference to the sign of b f e is made in order to make the rule applicable to all cases.

4. Fig. 1 admits of a large number of modifications, to each of which the General Rule is applicable, but in some cases special rules may be

derived which involve less labor. Thus, for the general railroad solid, Fig. 4, with any number of levels in the cross-section, the terms in the volume according to the prismoidal formula are:

(a) For each longitudinal edge, except the extreme surface edges,

$$\frac{1}{324} L (2h + h') b f e \text{ and } \frac{1}{324} L (2h' + h) b f e'$$

(b) For each extreme surface edge,

$$\frac{1}{324} L (2h_s + h_s') (\frac{1}{2} w - c a e)$$

$$\text{and } \frac{1}{324} L (2h_s' + h_s) (\frac{1}{2} w' - c a e'),$$

where h_s, h_s' = the heights at the ends of an extreme edge;
w, w' = the widths of the roadbed at the two ends,
c a e, c a e' = the horizontal distances, at the two ends, from the center to the edge adjacent to the extreme edge.

EXAMPLE.—Assuming that the length of the solid shown in Fig. 4 is 40 ft., the width of the roadbed P Q = 14 ft., and P' Q' = 20 ft., let the notes be

A'	D'	C'	B'	
25 / +15	18 / +20	0 / +18	20 / +10	$(\frac{1}{2} w = 10)$
17 / +10	6 / +16	0 / +17	5 / +18	22 / +15 $(\frac{1}{2} w = 7)$
A	D	C	E	B

The terms corresponding to each edge, except the two extreme edges A A' and B B', are formed in the same way as in the General Rule. Those for the extreme edge A A' are as follows:

At the end A, twice the height at that end + the height at the other end = 2 × 10 + 15 = 35; the adjacent edge is A D' as that cae is the horizontal distance from C to A = 17, and hence ½ w — cae = 7 — 17 = — 10; therefore the term is

$$\frac{1}{324} \times 40 \times 35 \times (-10).$$

At the end A', twice the height + the height at the other end = 2 × 15 + 10 = 40; cae at this end in the horizontal distance from C' to D' = 18, and hence ½ w — cae at this end = 10 — 18 = — 8; therefore the term is

$$\frac{1}{324} \times 40 \times 40 \times (-8).$$

The terms in the volume corresponding to each edge, with the resulting partial volumes, are:

Edge,	Terms.	+ Vols.	— Vols.
A D'	$\frac{1}{324}$. 40 . 40 . 11*	54 26/81	
D D'	" " 50 . 7†	43 17/81	
D C'	" " 52 . 17	109 11/81	
C C'	" " 56 . 18	124 36/81	
C B'	" " 52 . 11	70 50/81	
E B'	" " 53 . 38	248 52/81	
A A'	" " 46 . 22	124 76/81	
B B'	" " 38 . 20	93 67/81	
	" " 35 . (— 10)‡		43 17/81
	" " 40 . (— 8)‡		39 41/81
	" " 40 . (+ 2)§	9 71/81	
	" " 35 . (— 10)§		43 17/81
		879 1/81	125 75/81
		125 75/81	
		753 7/81 cu. yds.	

* Between A and D; A A' is the back edge.
† Between A' and D'; D D' is the forward edge.
‡ A D' is the adjacent edge; ½ w = 7, ½ w' = 10.
§ E B' is the adjacent edge; ½ w = 7, ½ w' = 10.

5. In the average end area method, the formula for the volume, in cubic yards, of a right prism with the length ½ L may be separated into a number of terms, one for each height, each of which will be the product of three factors divided by 108.

These terms may be written as follows:

If, in Fig. 5, we move a pencil point clockwise around the end section, — from A to B to C to D to E to F and so on, — of any three consecutive heights (say N B, O C and P D), one (O C) is the middle height, one (P D) is the forward height, and one (N B) is the back height. Let

h = any height, O C for example:

BFH = the horizontal distance between the back and forward heights, negative when the forward height is to the left of the back height; and

L = the perpendicular distance between the adjacent cross-sections.

Then the term, in the formula for the volume, between the two cross-sections, that involves h is

$$\frac{1}{108} L h . BFH$$

With the cross-sections shown in Fig. 5, there will be 7 terms, some of which will be negative, and their algebraic sum will give the volume of the right prism with this cross-section and with the length ½ L.

6. In applying the average end area method to the general railroad cross-section with any number of levels, the terms in the volume of a right prism with the given cross-section and with the length ½ L are

(a) For each height except the extreme side heights.

$$\frac{1}{108} L h . BFH.$$

(b) For each extreme side height.

$$\frac{1}{108} L h_s (\frac{1}{2} w - c a h)$$

where c a h is the horizontal distance from the center to the height adjacent to the side height.

EXAMPLE.

EXAMPLE.—Using the notes in Section 4, but neglecting the longitudinal lines, the terms are:

For the height at	Terms.	+ Vols.	— Vols.
D	$\frac{1}{324}$ × 40 × 16 × 17	100 20/27	
C	" " 17 . 11	69 7/27	
E	" " 18 . 22	146 18/27	
A	" " 10 (+ 1)*	3 19/27	
B	" " 15 (+ 2)†	11 3/27	
D'	" " 20 . 25	185 5/27	
C'	" " 18 . 38	253 9/27	
A'	" " 15 (— 8)‡		44 12/27
B'	" " 10 (+ 10)‡	37 1/27	
		807 1/27	44 12/27
		44 12/27	
		762 16/27 cu. yds.	

* The adjacent height is at D.
† The adjacent height is at E.
‡ The adjacent heights are at D' and C' respectively.

7. The factors in these terms, whether for the prismoidal or for the average end area method, may be taken directly from the notes, without drawing the cross-sections.

8. The value of each term may be determined, when L = 100 ft., by the use of a proper table, or from a diagram properly constructed, or with a slide rule. Thus, to compute the value of

$$\frac{100}{324} (2h + h') . b f e$$

with the Mannheim slide rule,

Opposite (2 h + h') on scale A, set 3.24 on scale B;

opposite bfe on B, read the volume on A.

9. The writer has prepared a circular slide rule which will give the value of any one of these expressions for any length L, without any uncertainty in the position of the decimal point, with an error not exceeding 1 in 400 or 1 in 500—well within the limits of error due to imperfect measurements.

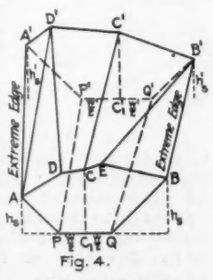


Fig. 4.

A Typical Railroad Prismoid.

This instrument will enable the engineer to determine mechanically the volume of earthwork in railroad construction, or the volume of any solid whose ends are in parallel planes and whose longitudinal surfaces are either planes or portions of hyperbolic paraboloids, being applicable to any width of road bed, to any center height, to any length, to any side slope ratio, to sections determined by any number of levels or by the transverse slope of the ground, and to side hill work, without requiring the plotting of the end sections.

It will give the volume, whether in cut or in fill, either according to the prismoidal formula or according to the average end area method, when the end sections are determined by any number of levels, and also the correction to be applied to the volume determined by the average end area method to obtain the volume according to the prismoidal formula. When the surface is determined by its tranverse slope, the instrument will give the volume according to the average end area method; but the slide rule will, in this case, enable the computer to determine the distances out and the elevations of the slope stakes, and then the volume according to the prismoidal formula, if it is desired.

The instrument consists of a card board disk, 15 ins. in diameter, called the BASE, and, concentric with the BASE, a second card board disk, 12½ ins. in diameter, called the ROTATOR, which may be rotated about an axis through the centers of the two disks. A strip of transparent celluloid, rotating around the same axis, extends beyond the scales on the BASE, and is marked with a radial line called the MARK, which enables the user to note the points, on the scales, which lie in the same radial line.

The BASE bears two closed circular logarithmic scales; on the outer, called "S," the numbers range from 4 to 400, and on the inner, called "A," they vary from 1 to 10,000.

The ROTATOR bears three closed logarithmic scales, called "B," "E" and "P," on which the

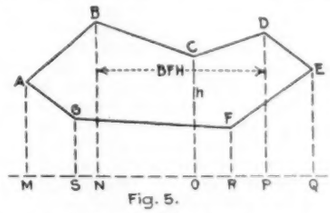


Fig. 5.

A General Cross-Section.

numbers range from 0.1 to 1,000. "P" is used in connection with the prismoidal formula, while "E" is more closely connected with the average end area method.

Since the scales are logarithmic, the instrument performs the operations of multiplication and division by the mechanical addition and subtraction of logarithms.

Scales A, B, and E are used to find the value of an expression which is in the form $\frac{1}{108}$ a b c.

For example, to find the value of $\frac{40 \times 50 \times 60}{108}$, first note, on scale A, the position of the line numbered 40; then move the ROTATOR until the line, on scale B, numbred 50 is in the same radial line with this 40; then place the MARK over the line, on scale E, numbered 60 and read on scale A the number corresponding to this position of the MARK, this number 1,111 1-9 being the value of the expression.

The word "opposite" being used as meaning "in the same radial line with," the preceding paragraph may be stated as follows:

Opposite 40 on A, set 50 on B;
opposite 60 on E, read the value on A.

Scales A, B and P are used to find the value of an expression which is in the form $\frac{1}{324}$ a b c, the third factor being found on P instead of on E; thus, to find the value of $\frac{40 \times 50 \times 60}{324}$,

Opposite 40 on A, set 50 on B;
opposite 60 on P, read the value 370 10-27 on A.

In using the scales A, B and E, or A, B and P, we find any one of the three factors (a, b, c) on A, and then opposite it set either of the other two, found on B; then opposite the third factor, found on E or P as the case may be, read on A the value of the expression.

The scale S is used, in combination with the other scales, to determine the volume of the "grade prism," and also for the determination of the volume, according to the average end area method, when the center height above grade and the transverse slope of the ground have been measured.

The scale A, on which the results are read, is nearly 40 ins. long, and it is numbered up to 10,000 cu. yds.

THE NEW STEEL ARCH STREET BRIDGE ACROSS THE POTOMAC RIVER, WASHINGTON, D. C.

One of the most interesting among the important bridges now being built by the U. S. Government in its public improvement work in the District of Columbia is the new steel arch bridge which is to replace the old Anacostia Bridge across the eastern branch of the Potomac River. This bridge is under contract to be completed by Jan. 1, 1907, and construction is now in progress. The cost of the work will be $375,000.

GENERAL DESCRIPTION.—As shown by the general elevation, Fig. 1, the bridge is 1,000 ft. long from face to face of abutments; it is composed of six three-hinged arch spans and one bascule draw span at the center, all carried by concrete piers and abutments. Four of the piers are uniform in size and 15 ft. thick at mean high water level and two, those at the ends of the draw span, are 31 ft. thick at the same level. The arch ribs are plate girders with hinges at crown and skewbacks, and plate girders are also employed in the draw span. There are six lines of arch ribs, but only two lines of girders in the draw span. The width of the bridge is 48 ft. between hand railings, this width being divided into two 6½-ft. sidewalks and a 35-ft. roadway with two street-car tracks. The roadway platform is carried on posts rising from the arch ribs. Each rib is divided into 14 panels and the posts rise from the panel points; each row of posts across the bridge carries transverse floorbeams, which support the stringers and floor system of buckle plates filled with concrete and paved with asphalt.

SUBSTRUCTURE.—The substructure of the bridge consists of four arch piers, two draw span piers and two abutments. The work is notable chiefly for the use of concrete for the entire structure of both piers and abutments, and for the pains taken to secure pleasing architectural treatment. Details of one of the smaller piers are shown by the drawings of Fig. 2. Among the points to be noted are the steel I-beam grillages set into the concrete to give bracings for the arch ribs and the parapet wall construction in sections keyed together by cement dowels. The draw-span piers are of more complex design, as shown by the drawings of Fig. 3. The use of reinforcement at several points plainly indicated will be noted.

To construct the piers the sites were first dredged and piles driven, as shown by the plans, Figs. 2 and 3, until they gave refusal of 1-3 in. penetration under a 2,000-lb. hammer falling 15 ft. It was specified that the piles should be pine or oak 12 ins. in diameter, 3 ft. from the butt and 6 ins. in diameter at the smaller end. After driving the foundation piles they were sawed off to uniform level and filled around and between with sand to within about 1 ft. of the tops. A cofferdam was then constructed around the piles and concrete deposited through a tremie until the bottom was sealed and the enclosure could be laid dry. The remainder of the concreting is to be done in the open in suitable forms.

The abutments are hollow or U-shaped in plan, are built of concrete, and are founded on piles; the construction is in all respects similar to that of the piers.

The materials of the substructure is concrete; this was required to be of the following compositions:

Class A shall be used for all concrete deposited under water.

Class B shall be used for the construction of the operating and tool houses, for all work on the piers and abutments above the bottom of the coping, and for facing all piers near water line.

Class C shall be used for the base of the roadway of the fixed spans.

Class D shall be used for all other work.

The contractor may use broken stone or gravel, as he desires, for all concrete under this contract, but having selected either one or the other, he must adhere to such selection.

CLASS A.—This concrete shall be composed of 1 part cement, 2 parts sand, and 5 parts broken stone or gravel. Broken stone shall be run-of-crusher, which can pass through a ring 2½ ins. in diameter, and which shall not contain more than 10% of stone dust which can pass through a screen having 10 meshes to the lineal inch. Gravel shall not contain pebbles greater than 2½ ins. in their largest dimensions.

CLASS B.—This concrete shall be composed of 1 part cement, 2 parts sand, and 4 parts broken stone or gravel. Broken stone shall be run-of-crusher, which can pass through a ring 1 in. in diameter, and which shall not contain more than 15% of stone dust which can pass through a screen having 10 meshes to the lineal inch. Gravel shall not contain pebbles greater than 1½ ins. in their largest dimensions.

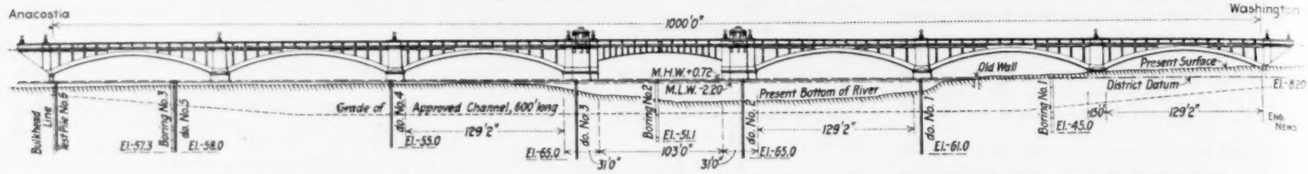
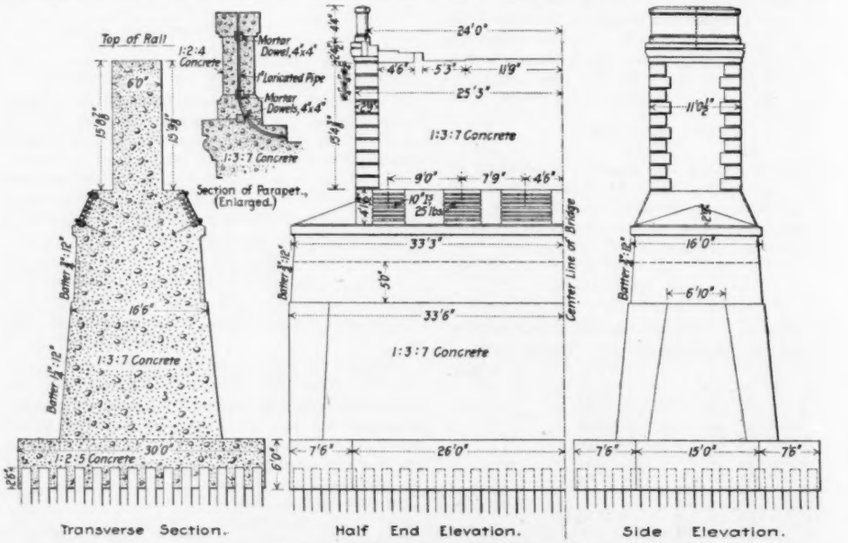


FIG. 1. GENERAL ELEVATION OF STEEL ARCH BRIDGE UNDER CONSTRUCTION ACROSS THE POTOMAC RIVER, AT WASHINGTON, D. C.

CLASS C.—This concrete shall be composed of 1 part cement, 3 parts sand, and 8 parts broken stone or gravel. Broken stone shall be run-of-crusher, which can pass through a ring 2 ins. in diameter, and not more than 10% of which can pass through a screen having 10 meshes to the lineal inch. Gravel shall be as specified for Class B.

CLASS D.—This concrete shall be composed of 1 part cement, 3 parts sand, and 7 parts broken stone or gravel. Broken stone or gravel below low water shall be as specified for Class A concrete. Broken stone above low water shall be as specified for Class C concrete. Gravel above low water shall be as specified for Class B concrete.

The concrete was required to be deposited in 6-in. horizontal layers and compacted by ramming.



In joining fresh concrete to concrete already set, the older material was required to be thoroughly cleaned and covered with ¼ in. of mortar, or if not over seven days old with a wash of 1-2 grout. No concrete can be laid at temperatures below 30° F. The specification for surface finish is as follows:

The trimming surfaces of the bridge (the exterior of the operating and tool houses, coignes, coping, belt course, parapet, etc.) shall be covered with a coating of 1 in. Portland cement mortar (1:3), which shall be placed at the same time as the concrete back of it, so that there shall be no line of weakness between the mortar facing and the aforesaid concrete. All other showing faces of the bridge shall be carefully spaded so as to present a smooth finish upon the completion of the work. Extreme care shall be taken to make all arrises to true and full lines.

ARCHES.—Each of the six arch spans has six plate girder ribs 4½ ft. deep spaced 9 ft., 7 ft. 9 ins., 9 ft., 7 ft. 9 ins. and 9 ft., from side to side of the bridge. The arch ribs have a span of 128 ft. 1½ ins. between end pin centers and a rise of 14 ft. 6 ins. The arch ribs are braced together at panel points by lattice girders set coincident with the radius at each point. There is also lateral bracing between the bottom flanges of the four intermediate girders pair by pair. The outer ribs are somewhat lighter than the intermediate ribs and are modified at the hinges, as shown by the drawings of Fig. 4, but the general design and construction of all ribs are substantially the same. Fig. 4 shows details of the skewback and crown connections of all ribs. It will be noted that the pins locks the two half ribs together at the crown and also each half rib to its corresponding skewback shoe, and that the outer ribs are provided with web cover plates, which mask the three pin joints. Other details are sufficiently emphasized by the drawings.

SPANDREL BRACING.—Counting each way from the center pin each arch rib is divided into six 10-ft. 1½-in. panels and one shorter panel at the end. From each panel point rises a column or post supporting the roadway. The character and composition of this bracing are clearly indicated by Figs. 5 and 6. The vertical sway bracing between columns shown in Fig. 6 is omitted for all except the two longer posts at the ends of each span, and at the crown of the arch as shown the posts disappear altogether.

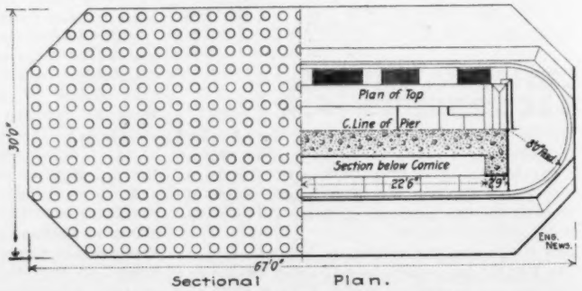


FIG. 2. PIERS FOR ARCH SPANS.

FLOOR SYSTEM.—Each transverse row of spandrel columns carries an I-beam transverse girder or floor beam. These transverse beams carry stringers, which in turn support the floor

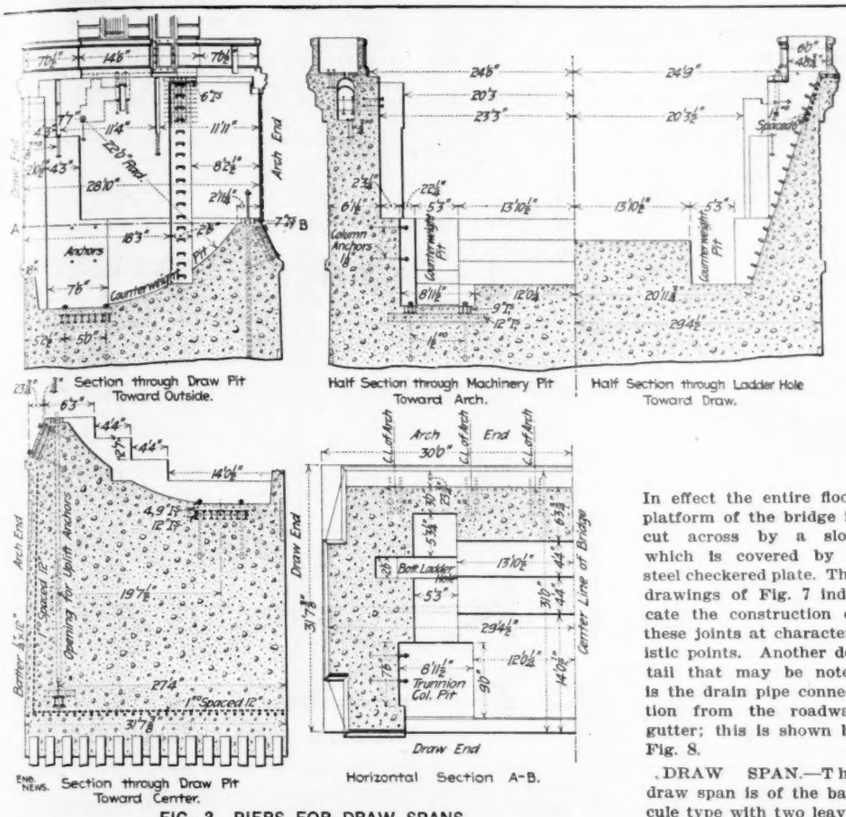


FIG. 3. PIERS FOR DRAW SPANS.

buckle plates. The arrangement is shown by Fig. 6, which also shows how the outer portions of the sidewalks are bracketed out over the outside line of posts. An important feature of the floor construction is the expansion joints at crown of arch and center line of pier and at the abutments. In effect the entire floor platform of the bridge is cut across by a slot, which is covered by a steel checkered plate. The drawings of Fig. 7 indicate the construction of these joints at characteristic points. Another detail that may be noted is the drain pipe connection from the roadway gutter; this is shown by Fig. 8.

DRAW SPAN.—The draw span is of the bascule type with two leaves joining at the center of the span. Each leaf consists of two girders connected across the bridge by floor beams, and the system of floor bracing is shown by the plan Fig. 9. The girders are hung on trunnions A A, and have rearward extending arms carrying counterweight boxes. Each trunnion is supported by the parallel frameworks composed of the pillars B and the trusses C; the counterweight box has space between these frameworks. Power to operate the leaf is applied, from a motor through a train of shafts and gears, to a pinion which meshes with a rack D attached to the bottom flange of each girder just below the trunnion. When lowered the ends of the two leaves are locked together at the girders by a latch arrangement.

So much for the general arrangement shown in Fig. 9. The essential details are the girders and their attachments, the structures supporting the trunnions, and the operating mechanism. The general form of the girders is shown by the elevation, Fig. 9. They are plate girders, with a uniform depth of 10 ft. for 28 ft. 8½ ins., at their rear ends; from this depth they taper up on the bottom flange to a depth at the end of 4 ft. ¾ in. Fig. 10 shows a portion of the rear end of one girder, giving details of the counterweight box, trunnion bracing and operating rack. Old iron and concrete, to weigh not less than 350 lbs. per cu. ft., was used for filling the counterweight box, which is planned to be so loaded that the center of gravity of the girder will fall between 6 and 8 ft. in front of the trunnion. The front end construction of the girder is shown by Fig. 11. These drawings show particularly the endlocking arrangements; they need no further description.

The drawings of Fig. 12 show the trunnion supports. Practically the only details that call for more specific presentation are the buffer on the rear cross girder, which receives the shock of the rising tail end of the main girder, and the wedge seat on the top flange of the forward cross girder. The last detail is expected to add materially to the stiffness of the bridge.

The operating mechanism is all controlled from operating houses located on the tops of the draw piers, as shown by Fig. 9. To balance these operating houses, only two of which are required, the designers placed tool houses of exactly similar appearance on the opposite ends of the piers. These houses are all built of reinforced concrete to correspond in material and finish with the concrete piers on which they stand. Details of the

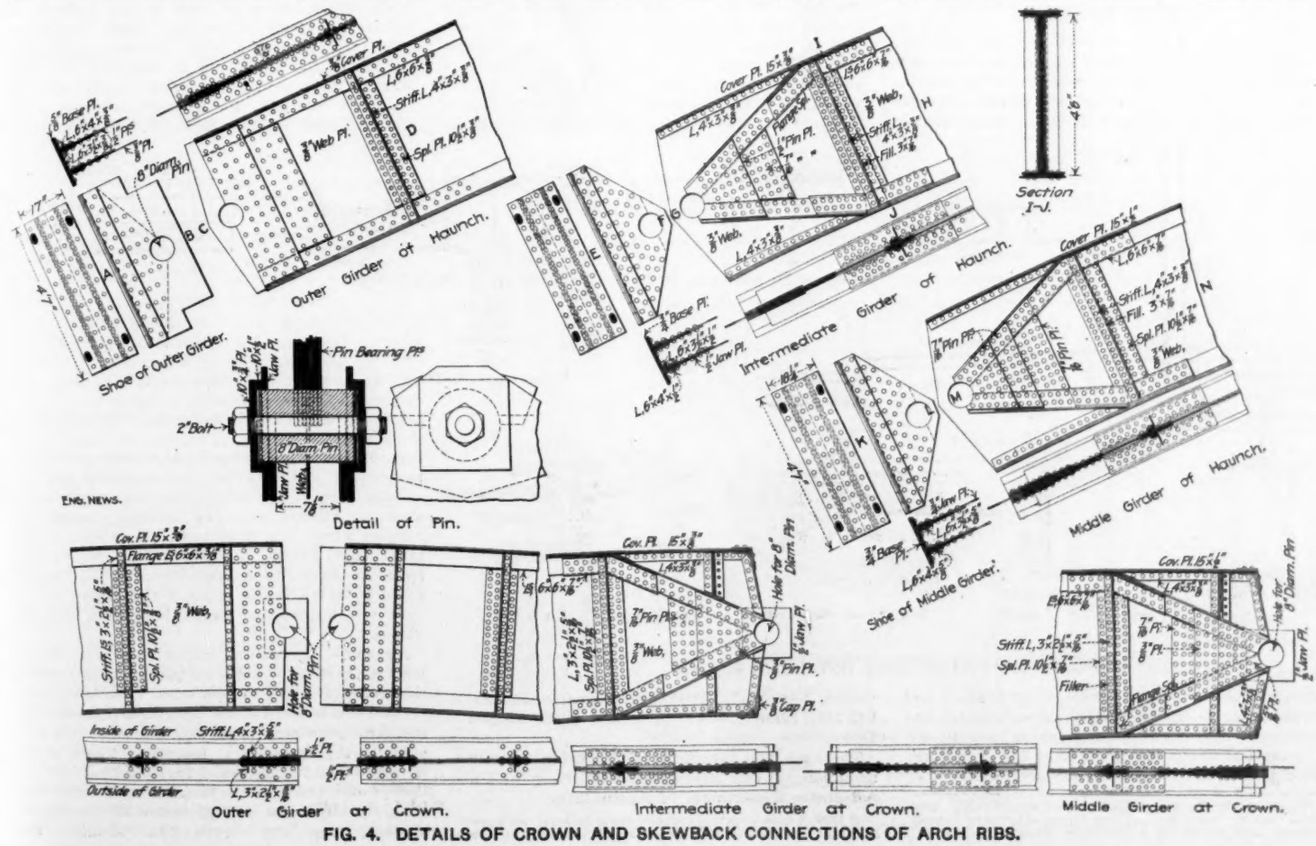


FIG. 4. DETAILS OF CROWN AND SKEWBACK CONNECTIONS OF ARCH RIBS.

reinforced concrete work for one of the operating houses are shown by Fig. 13.

The structural steel for the main part of the bridge was specified to be open hearth steel made according to the Manufacturers' Standard Specifications for Steel for Highway Bridges. The specifications for steel castings, cast iron, workmanship, etc., correspond to general practice in first class bridge work.

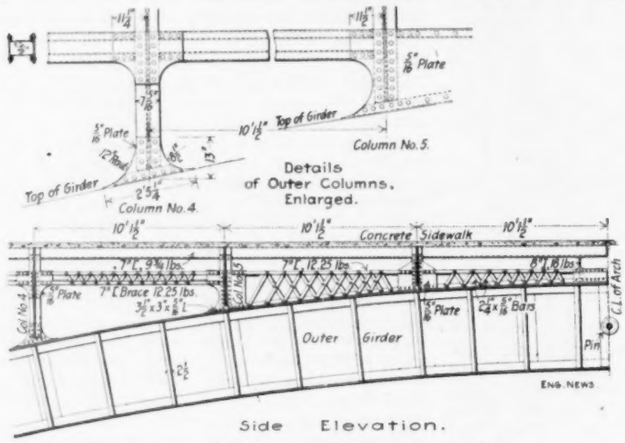


FIG. 5. GENERAL DETAILS OF SPANDREL BRACING.

The bridge was designed in the office of the Engineer of Bridges, Mr. W. J. Douglas, under the direction of Col. John Biddle, Engineer Commissioner, District of Columbia; Capt. J. J. Morrow, Assistant to the Engineer Commissioner, Mr. C. B. Hunt, Engineer of Highways, assisted by Mr. T. B. Wilson, in charge of the structural work; Mr. T. C. J. Baily, Jr., in charge of foundations; Mr. Charles Hilmer, in charge of machinery; and Mr. H. T. Pratt, in charge of architectural design. We are indebted to Mr. W. J. Douglass for the information from which this description has been prepared.

TEACHING AGRICULTURAL ENGINEERING IN LAND GRANT COLLEGES.

By C. J. Zintheo.*

By land grant colleges, I take it, is meant such institutions as have been organized in the various states in the Union under the Morrill Endowment Acts of 1862 and 1890, to establish and maintain colleges for the benefit of agriculture and mechanic arts. These colleges of agriculture and mechanics arts have been great factors in advancing knowledge along the lines for which they were intended. The mechanic arts sections of these institutions have been developed into engineering colleges and most of them are now offering courses in mechanical, civil, electrical and mining engineering.

The agricultural colleges and experiment stations are making investigations and giving instruction in almost all branches of agriculture, teaching the farmers how to improve their breeds of cattle and grains, how to increase the fertility of the soil, and how to bring farming up to a scientific and business basis of management. It was evidently intended by the Morrill Act that the courses in agriculture and mechanic arts should strengthen and help each other. They have, however, diverged so that the engineering courses are now entirely professional courses for the varied industries, and the agricultural students have received no mechanical training except the small fraction of time devoted to manual training, such as carpentry and blacksmithing. While this training is good so far as it goes, it certainly is not sufficent for the average agricultural student, in view of the importance of machinery on the farm to-day. To give an idea of the vast sums of money that are invested in farm implements, take, for example, the following five states: Iowa has $57,960,000 invested; New York $56,006,000; Pennsylvania, $50,917,240; Illinois, $44,977,319, and Ohio, $36,354,150.

The time and money saved by using improved machinery is well shown in the report of the United States Department of Agriculture:

In 1830 it took over three hours' labor to raise one bushel of wheat; in 1896 it took ten minutes; in 1830 the labor in one bushel of wheat cost 17¾ cts.; in 1896 it cost 1½ cts. per bushel.

In 1850 the labor represented in a bushel of corn was 4½ hours; while in 1894 it had been reduced to 41 minutes. In 1890 it is estimated that the labor to produce a ton of hay in bales represented 35½ hours, while in 1896 this labor was reduced to 11½ hours, or from a cost of $3 in labor to $1.29.

The report estimates that in 1899 the agricultural implements in the United States saved in human labor the sum of $681,471,827.

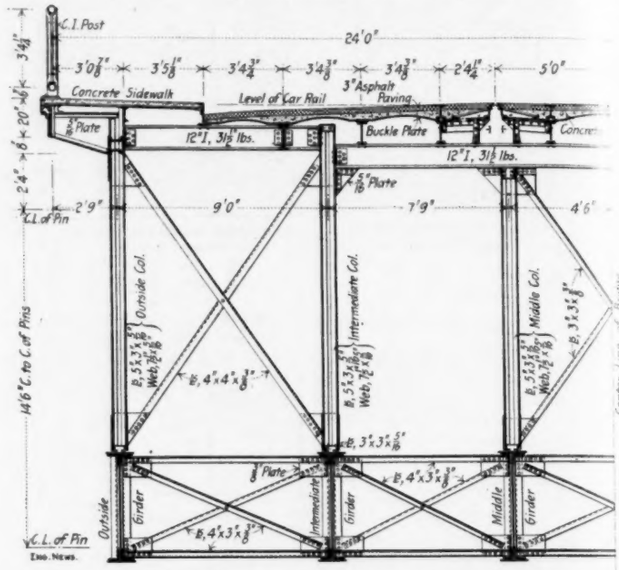


FIG. 6. HALF-TRANSVERSE SECTION OF ARCH SPAN.

In no other country is such extensive use made of farm machinery, and the scarcity of farm laborers will tend to increase its use in the future rather than otherwise. The total value of the implements and machinery on the farms of the United States, according to the recent census, was $761,261,550, an average of $133 per farm, taking the country over, and 90 cts. per acre of farm land. Truly, no other item in the farmers' investment, outside of the land itself, requires so much capital upon which he must pay interest.

Much of the machinery is elaborate and complicated in its construction and requires mechanical skill or genius for its most efficient operation and care, not to mention the making of special repairs. That there is an enormous waste of money due to the neglect and unskilful handling of this part of the farm equipment must be obvious to anyone who has traveled through the regions where it is most used. It is safe to estimate that nearly one-half of the money now spent for agricultural implements in this country could be saved if the farmers understood how to care for, adjust and properly operate the machines.

American agricultural colleges are a good way behind those of Europe in the work of training the students in mechanical work. The little country of Switzerland has, for many years, been making farm implement field exhibits under the auspices of the agricultural societies. These exhibits are well advertised and farmers from far and near come and receive instruction in the use, abuse, construction and operation of the various kinds of farm implements. In Germany and

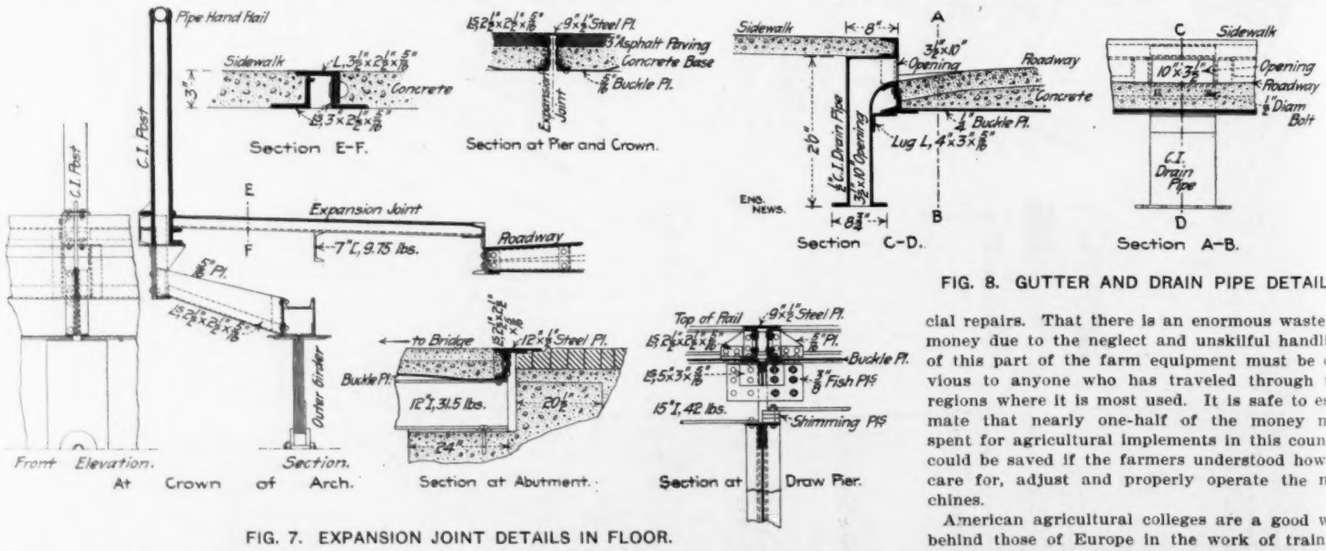


FIG. 7. EXPANSION JOINT DETAILS IN FLOOR.

FIG. 8. GUTTER AND DRAIN PIPE DETAIL.

*Formerly Professor of Agricultural Engineering, Iowa State College; now in charge of Farm Machinery Investigations, Department of Agriculture, Washington, D. C.

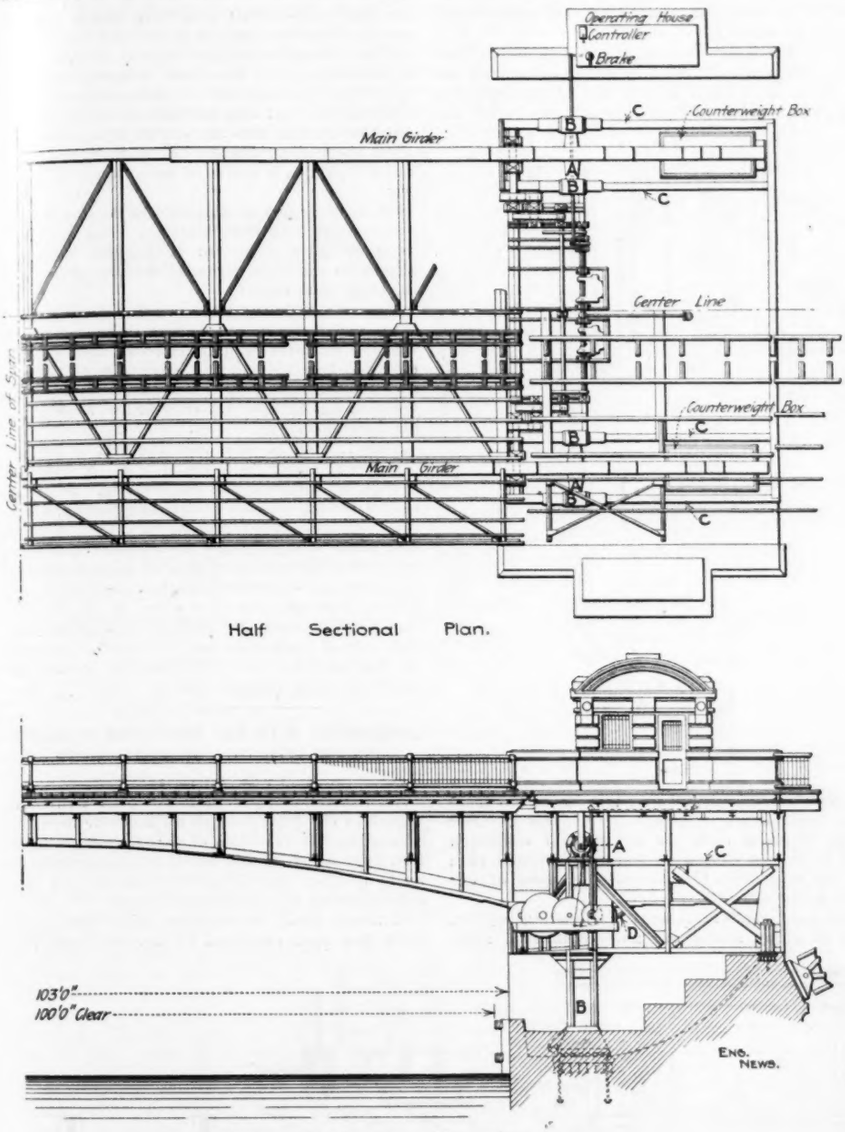


FIG. 9. GENERAL PLAN AND ELEVATION OF BASCULE SPAN.

France field trials are annually conducted between the various makes of farm machinery. These trials are carried on by the Government and are largely attended by the farmers.

The agricultural high school at Berlin has a well developed and efficient department of farm machinery. In the opinion of the head of that department nothing has done more to improve the agricultural methods in Germany than the study by the young men of the tools of their own and other countries; and out of it have resulted many improvements in construction.

In England agricultural shows are held throughout the summer, at which instruction is given in farm machinery.

The Scandinavian countries are making tests of farm machinery, and the Society of Norway's Welfare is annually conducting experiments with agricultural implements and issuing bulletins in which are published the results of their observations for the benefit of the farmers.

The Russian agricultural college students are obtaining practice in judging farm machinery according to certain laid-down principles in about the same way that our students are judging pure bred cattle and horses. Even in far off Siberia the writer had the privilege, a few years ago, of attending the field trial between the various makes of American harvesting machines. The trial was held at the agricultural college at Tomsk, Siberia. After the trial the machines were taken down by the college students and each part studied in detail under the supervision of the college director and the instruction of the American experts.

The first work looking toward instruction in farm machinery by any American Agricultural college, was, no doubt, done in Wisconsin by Prof. F. H. King He conducted a number of experiments with windmills, pumps and feed grinders, as well as along the line of drainage and irrigation, and taught the subject to the students under the name of agricultural physics. In 1898 the legislature of Illinois appropriated money for a building for farm mechanics, and since that time a course in farm mechanics has been offered at that institution and instruction given in setting up farm machinery and similar objects.

The North Dakota agricultural college has for a number of years maintained a similar course in farm mechanics, and has had the co-operation of farm implement salesmen, who come to the college and give talks to the students, explaining the construction of the machines that they sell, by having the machines brought right into the classroom before the students.

The Wisconsin College has received a state appropriation of $15,000 for a farm engineering building, which is being erected, and a department of farm engineering has been put in charge of a man to teach the subject.

The Minnesota College of Agriculture has obtained an appropriation of $5,000 for a building for its course in rural engineering, and the officers of the state fair have granted the college the use of a large pavilion in which machines loaned by the manufacturers are to be housed for instructional purposes.

The Iowa Agricultural College, at Ames, has, however, made the largest progress in the establishment of a complete course in agricultural engineering. A very substantial building four stories high has been erected. The building is constructed of brick, stone and steel and is fireproof throughout. The cost, including heating and plumbing, furniture and other equipment, is between $65,000 and $70,000. The course, as outlined, will extend over three years, beginning with the sophomore college year. All students in the agricultural courses are required to take one year in farm mechanics, which embraces the study of the elementary principles and practice of tile drainage, road construction, irrigation, farm implements of all kinds, farm motors, such as gasolene engines, traction engines and separators, carpentry, blacksmithing, horse shoeing, mechanical drawing, farm building construction, etc. In no other institution are all these courses brought together under one head. While in most agricultural colleges instruction is usually given in carpentry and blacksmithing, it is usually given in the engineering courses, and it is feared too much attention is given to the manual training style of instruction and not enough attention paid to the actual requirements of farm students. In Iowa these subjects are given the attention they merit. The boys are not making "play things" but are making neck yokes, whiffletrees, wagon tongues, racks, fence gates, windows, doors, etc. In the blacksmith shop they are ironing the articles made in the wood shop, and are taught how to

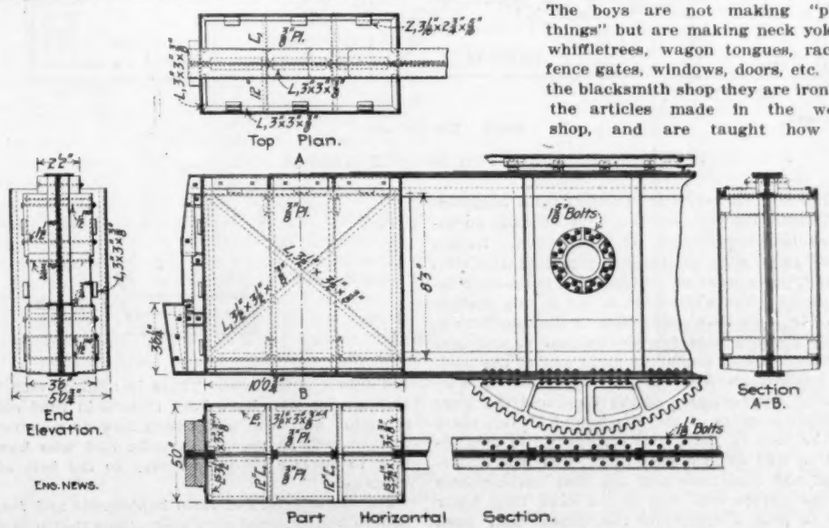


FIG. 10. DETAILS OF COUNTERWEIGHT END OF BASCULE GIRDER.

set wagon tires, sharpen plow lays, rectify horseshoes, shoe horses and do the actual repair work of farm machinery. In the machine operation rooms the students are taught how to set up and adjust binders, mowers, corn harvesters, shredders, drills, etc. The binder attachments and knotters are stripped to the frame and rebuilt by the students, after which they are placed on the "try off rack" and put in motion. Straw is run through them and tied into bundles. If, for any reason, the machines do not tie, the students have to adjust the machines until they work properly. In the junior and senior year elective and advanced courses are offered. The various subjects of agricultural engineering, drainage, irrigation, machine design and building construction, as well as other subjects, are offered.

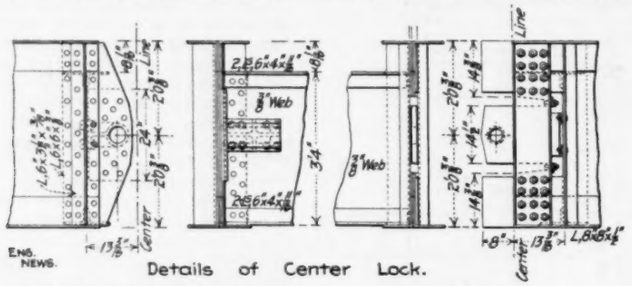


FIG. 11. DETAILS OF FRONT END OF BASCULE GIRDER.

Other colleges, such as the agricultural colleges of Indiana, New York, Ohio, and California, are now organizing courses along similar lines. While several different names have been used in connection with the instruction of the fragments of such a course, such as agricultural physics, farm mechanics, rural engineering, farm engineering, etc., yet a complete course of this kind should naturally be called agricultural engineering.

In each case where instruction of this nature is now carried on in colleges it has been inaugurated as a branch of instruction in agronomy. While this may answer as a beginning, the importance of the allied branches of rural engineering, taken together, entitles it to be made an independent department of instruction, having equal rank with agronomy or animal industry, as they have been established in a number of institutions. The work done so far is only preliminary to work that may follow in the near future.

The opportunities for professional agricultural engineers are as numerous as in any of the leading professions. With the advent of the large irrigation developments of the West and the large drainage projects of the Mississippi Valley, there will be need for men who are trained in agriculture as well as in engineering. Men who understand soil conditions and the best requirements for farm crops and who at the same time know how to plan a system of tile drains and open ditches, or who can plan the distribution of the irrigation water for a given district, will be very much in demand.

The westward movement of population has been the cause of taking up for settlement all the land in the United States that is available for easy cultivation. What remains has to be deemed for agricultural purposes by more expensive methods of irrigation. For this purpose there is great need for agricultural engineers, and such men cannot be trained elsewhere than in the agricultural engineering courses of our land grant colleges.

The good roads movement is spreading rapidly, and in many states are now established state highway commissions. There is need of men in this service who have been trained in road construction and who understand how to construct dirt as well as macadam roads, and who know how to operate road machinery to the best advantage.

The manufacture of farm implements and farm motors has assumed such proportions that it is no longer possible for the manufacturers to employ the kind of men that they have had in the past for experimenters and designers. What they need are men trained along agricultural lines who have experience in farm implement designing; the construction and operation of farm implements; in other words, men who understand agricultural requirements, and who can design the machines to meet these requirements. Such training can be secured only in a course of agricultural engineering.

There is a rapid development in the line of farm architecture. As the country is being settled it becomes quite important that farm buildings should be carefully planned, nicely arranged and carefully constructed.

With the scarcity and high price of lumber, cement and concrete are coming quite extensively into use for farm building purposes. Men who understand how to plan and execute work in farm architecture are very much in demand. This training can be obtained only in an agricultural engineering course.

Thus it may be seen that the field of agricultural engineering is a broad one. A complete course of agricultural engineering, therefore, should include courses in field engineering, drainage, irrigation, road construction, farm machinery, farm motors, farm architecture and farm implement designing, as well as a good share of research and experimental work. It should also include the agricultural courses in farm crops, soils physics, farm management, with some dairying, animal husbandry and horticulture, as well as the usual cultural and scientific studies included in other college courses.

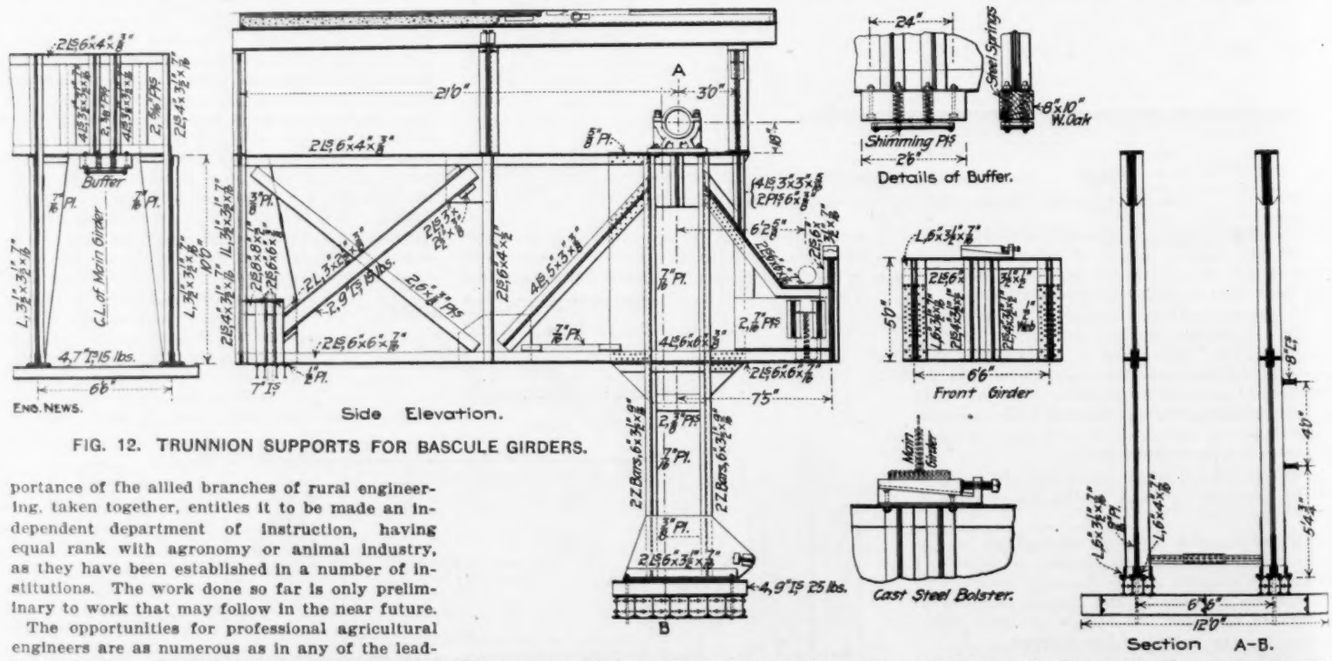


FIG. 12. TRUNNION SUPPORTS FOR BASCULE GIRDERS.

EXPERIMENTS WITH THE PITOT TUBE IN MEASURING THE VELOCITIES OF GASES IN PIPES.

By R. Burnham.*

Notwithstanding all that has been written in regard to the Pitot tube as an accurate means of measuring the velocities of fluids, doubt still exists, apparently, in the minds of many engineers as to whether the claims for it have been fully substantiated by experimental proof.

In nearly every investigation where the instrument has been employed its use has been preceded by a laborious calibration for the purpose of determining its true formula. The lack of accordance in the results obtained by different observers has, in some cases, been due to the experimental difficulties attending the work, and, more often, to the effect upon the rating of the form and dimensions of pressure tube used.

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The working formula for the Pitot tube is ordinarily taken as $v = K\sqrt{2gh}$, where K is a constant to be determined by experiment for the particular form of tube used. Some have claimed the true theoretical formula to be $v = \sqrt{gh}$. The writer has had occasion to use the instrument to some extent in the testing of fans and blowers, and in experiments connected with the flow of gases in pipes. In this latter connection an unusually favorable opportunity was presented, through the courtesy of Mr. C. W. Bradley, of the Peoples' Gas Light & Coke Co., to carry on a careful series of experiments for the purpose of rating Pitot tubes. These experiments were conducted by Messrs. H. A. Dreffein and Edw. McBurney, as the basis of a thesis in mechanical engineering. It is the object of this paper to describe briefly the method of conducting the experiments, and to present the results obtained as showing the practical accuracy of which the Pitot tube is capable.

A form of tube was designed which could easily be duplicated, and which at the same time conformed, in the main features, to forms reputed to give good results when used by other observers. The instruments, Fig. 1, were made up of two brass tubes, one within the other, the inner tube, 3-16-in. outside diameter and 1-32-in. thick, forming the velocity tube. The outer or pressure tube is made of ⅜-in. tubing, 1-32-in. in thickness, provided with a slot, 1-16 × 1¼ on the under side of the horizontal portion, for the admission of pressure. Tips of various forms may be attached to the velocity tube, but in the present case the ones shown were used. As a matter of fact it was demonstrated that the form of tip, within quite wide limits, makes no appreciable difference in the indications of the tubes. The pressures exerted were transmitted through rubber tubing, attached at B and G, to opposite sides of sensitive manometers, reading to thousandths of an inch of water. The arrangement of the tubes in the stuffing box, as shown, permits a longitudinal movement, and also some lateral adjustment, in the event of the hole in the pipe not being tapped exactly perpendicular to the axis. The position of the tube with reference to the center of the pipe is indicated on a graduated scale, by the pointer, T.

The facilities for carrying on the experiment consisted of two large illuminating gas holders having capacities of 900,000 and 2,000,0000 cu. ft., respectively, communicating with each other through a 24-in. cast-iron main, free from bends or obstructions of any kind for a length of about 150 ft. A Root exhauster, capable of delivering 17,000 cu. ft. per min., served to draw the gas from the smaller and deliver it into the larger holder, the velocity of flow being controlled by the speed of the exhauster. The normal pressure in the larger holder was several inches of water in excess of that in the smaller, which permitted the gas to be returned at any desired velocity by manipulation of a by-pass valve in the line.

Two Pitot tubes were inserted, near the middle of the straight portion of the pipe, and a thermometer midway between the tubes for indicating the temperature of the gas. One Pitot tube was used to measure the velocity at the center of the pipe, and was kept constantly in that position. The other tube was arranged to be moved across the diameter of the pipe, its exact position being indicated on a graduated scale. Both tubes were connected to manometers in such a way as to indicate at any instant the static pressure and the velocity head.

The true mean velocity of the gas was obtained by recording the rise or fall of the smaller holder, at frequent intervals during the run, and computing the volume displaced in cubic feet per second from the known dimensions of the holder. This, reduced to the temperature and pressure recorded at the Pitot tubes, and divided by the cross-sectional area of the pipe in square feet, gave the mean velocity in feet per second. The mean velocity is defined as that velocity which, when multiplied by the cross-sectional area of the pipe, will give the volume discharged. The theoretical *mean* velocity, according to the equation $v = \sqrt{2gh}$, was determined, in the manner explained later, from Pitot tube readings of the velocity head, taken at several points from ½ to 1 in. apart, across the diameter of the pipe. The ratio between the true mean velocity and the mean velocity as deduced from the Pitot tube was taken as the value of the constant K, in the formula $v = K\sqrt{2gh}$. Reliable data were secured for gas velocities of from 35 to 65 ft. per sec.

In computing the volume of gas flow from the holder displacement due account was taken of the correction due to expansion of the gas in the holder. Except when the sun was shining, however, the correction was practically negligible. The density of the gas was found to vary to some extent, hence frequent analyses were made, from which the weight per cubic foot was computed for each run.

Table I. shows the data obtained in a typical run, the mean velocity of the gas being 43 ft. per sec. It will be observed that the manometer readings were taken in inches of kerosene. These are reduced to inches of water by dividing by 1.038.

The theoretical velocity in feet per second is obtained from the Pitot tube manometer readings by substitution in the equation, $v = \sqrt{2gH}$, where H is the equivalent velocity-head in feet of gas, which becomes,

$$v = \sqrt{\frac{2 \times 32.16 \times 62.4}{D} \times \frac{h}{12}} = 18.288\sqrt{\frac{h}{D}}$$

where h is the velocity-head in inches of water ($h = H \div 1.038$), and D the weight of 1 cu. ft. of gas at the temperaure and pressure in the pipe.

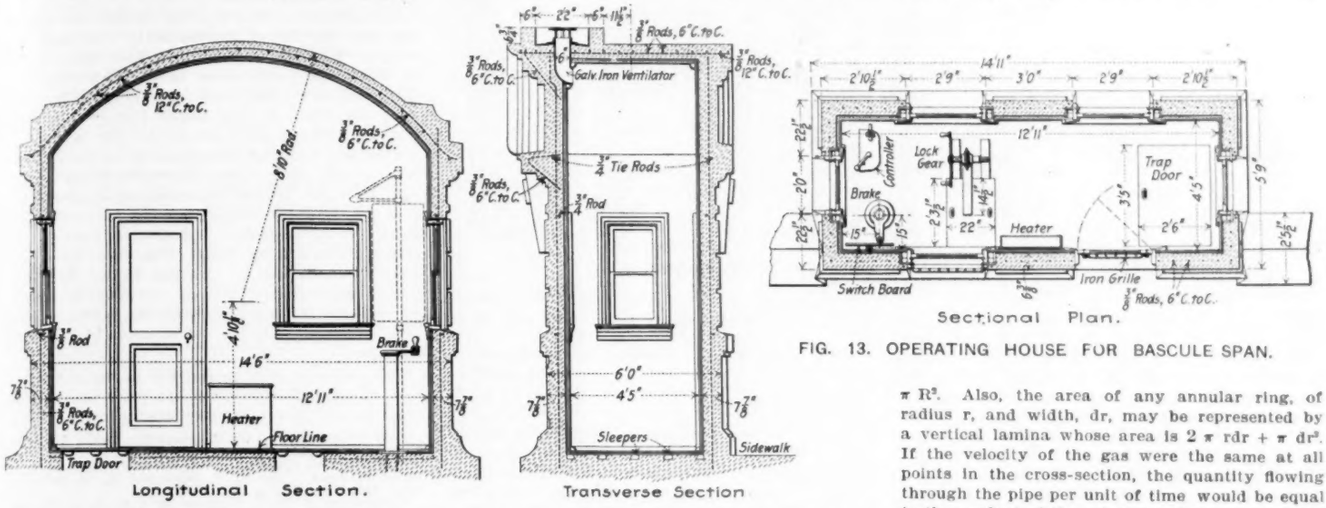

FIG. 13. OPERATING HOUSE FOR BASCULE SPAN.

The method of deducing the theoretical *mean* velocity from the Pitot tube readings will be understood by reference to Fig. 2. The area of the pipe cross-section is represented by a circle of radius, R. The right triangle O A B is so constructed that the base is equal to R, and the altitude equal to $2\pi R$. The area of the triangle, then, is equal to the area of the circle, πR^2. Also, the area of any annular ring, of radius r, and width, dr, may be represented by a vertical lamina whose area is $2\pi r dr + \pi dr^2$. If the velocity of the gas were the same at all points in the cross-section, the quantity flowing through the pipe per unit of time would be equal to the product of the velocity and the area O A B. The velocity is not uniform, however, but varies with the distance from the center, being assumed to be the same throughout any annular ring of width, dr. Hence the volume flowing might be found by taking the summation, throughout the section of all the products,

$$V_1(2\pi r_1 dr + dr^2) + V_2(2\pi r_2 dr + dr^2) + \text{etc.} = \pi VR^2$$

where V_1, V_2, etc., are the theoretical velocities as obtained from the Pitot tube readings at radii

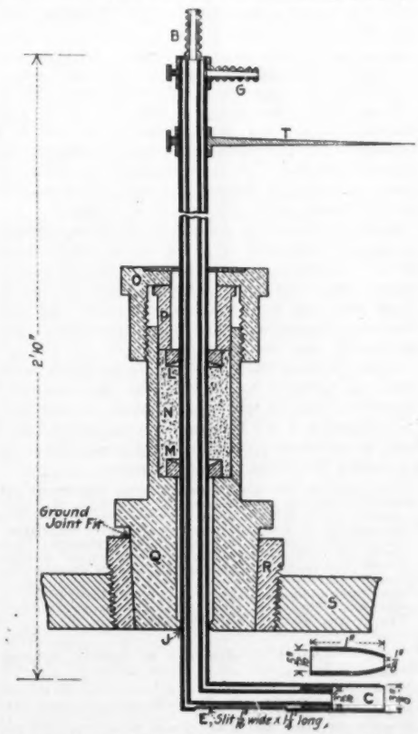

Fig. 1. Section Through Pitot Tube and Stuffing Box, Used on Gas Main.

r_1, r_2, etc., and V is the theoretical mean velocity. This is accomplished graphically, in a practical way, by laying off these velocities as B G = V_1 on any convenient scale, along the altitude A B. The intersection of O G and the ordinate erected at the extremity of the radius r, determines the

TABLE I.—DATA OBTAINED WITH A PITOT TUBE ON GAS MAIN DURING A TYPICAL RUN (NO. 3; MAY 25, 1905).

(Barometer, ins. mercury, 29.22. Pressure in holder, ins. water, 4.11. Weight of Gas per cu. ft., lbs., .0476. Average static head in pipe, ins. water, 4.52. Area of holder, 16,290 sq. ft. Diameter of gas main, 23.75 ins.)

Time.	Temp. of gas, Deg. F.	Holder displacement. ft.	ft. per min.	Velocity heads at center of pipe, ins. kerosene. H	$\sqrt{H}$	Velocity heads measured across diameter of pipe, ins. kerosene H	$\sqrt{H}$	Location of tube; distance from center, ins.
11:58	67.0	10.27		.355	.596	.340	.583	Center
			.484	.330	.574	.310	.556	1.44
12:05	65.1	13.66		.370	.608	.340	.583	3.44
				.375	.612	.320	.566	5.44
				.380	.616	.310	.557	6.44
			.496	.360	.600	.300	.548	7.44
				.380	.616	.290	.538	8.44
				.360	.600	.270	.519	9.44
12:10	63.2	16.14		.370	.608	.250	.500	9.94
				.370	.608	.240	.490	10.44
				.375	.612	.220	.469	10.94
				.375	.612	.155	.394	11.44
			.490	.370	.608	.220	.469	10.94
				.380	.616	.230	.479	10.44
				.375	.612	.245	.495	9.94
				.370	.608	.275	.524	9.44
12:15	63.0	18.59		.370	.608	.290	.538	8.44
				.380	.616	.300	.548	7.44
				.375	.612	.320	.568	6.44
				.370	.608	.330	.574	5.44
			.488	.370	.608	.340	.583	3.44
				.35	.592	.340	.583	1.44
				.365	.604	.355	.596	Center
12:20	61.8	21.03		.365	.604	.360	.600	"

Deduct .0009 ft. per min. from holder displacement to allow for expansion.
h, in inches of water = H ÷ 1.038.

point, P, on the curve O S P H. In a similar way other points are found. It can be shown, then, that the quantity of gas flowing per unit of time is proportional to the area under the curve. The mean velocity is found by constructing the triangle B O F equal to the area under the curve, whence B F is proportional to the theoretical mean velocity, and the intersection S determines the mean-velocity radius. If B E be laid off proportional to the actual mean velocity, as found by dividing the flow in cubic feet per second by

$$\frac{BEO}{BFO}$$

the area of the pipe, then ——— is the value of the constant K, in the equation, $V = K\sqrt{2gh}$. Since these relations hold, whatever the scale or units adopted, the $\sqrt{H}$ may be plotted instead of the computed velocity.

Fig. 3 shows the actual curve obtained from the data given in Table I.

Table II. gives a summary of the results obtained from six runs, showing the following average values:

Mean-velocity radius, 8.97 ins., or 70.4% of pipe radius.
Ratio of mean velocity to velocity at center .869
Constant K 1.003

From these experiments, then, it may be concluded that a Pitot tube of the form used is a perfectly reliable instrument for measuring the velocity of gases; its constant may be taken as equal to unity; it indicates velocity head exactly in accordance with the law, $v = \sqrt{2gh}$.

While the writer is not the first, by any means, to present experimental proof of the above facts, yet the applications of the Pitot tube to experiments with the flow of gases have been comparatively few, and not always accordant in the conclusions arrived at. He hopes, therefore, that the results may be of some interest.

As far back as 1873, Prof. S. W. Robinson made what he believed to be the first application of the Pitot tube to the flow of gases, in studying the velocities of air issuing from an orifice,* and later in measuring the flow from gas wells.† In discussing the Pitot tube he states,‡

It is probably the most nearly perfect instrument yet discovered for the measurement of velocities of fluids. It applies to liquids in open channels, or to all fluids from orifices, or through conduits, at low or high pressures, and gives results with remarkable precision. Thus there is no necessity for tedious calibration, or for the use of complicated coefficients. Its simple construction admits of its being made of glass tubing and rubber hose.

More recently the instrument has been used in connection with some experiments with ventilating fans* made by Capt. D. W. Taylor, U. S. N. The form of tube devised by him was similar in design to the one employed in the present experiments, and its constant was taken as equal to unity. Quoting from the paper above referred to, Captain Taylor draws the following conclusions based upon his careful investigation of the Pitot tube question:

The Pitot tube has been more or less discredited in the past as an appliance for measuring the velocity of fluids, many having maintained that the theoretical formula is inaccurate. As a matter of fact the difficulty has been with the type of tube. As regards the impact portion of the tube there is no difficulty. Experiments, notably those by Mr. W. M. White, described in a paper before the Louisiana Engineering Society,† in May, 1901, entitled, "The Pitot Tube—Its Formula," demonstrated conclusively that for water, considering the impact side of the tube only, the theoretical formula is practically exact. As regards the pressure side it is necessary to communicate the pressure in the moving current of air to the air at rest within the tube. This obviously can be best done by having a tube of such shape and proportions as to disturb as little as possible the natural pressure in the moving current, and to maintain as long as possible contact between the moving current and the air at rest within the tube. Pitot tubes in which the pressure openings consist of small round holes must be necessarily inaccurate, as the aspiration effect of a moving current across such an opening is large and irregular. Experiments in currents of air with such Pitot tubes as are shown show no aspiration effect. Prof. A. F. Zahm, of the Catholic University in Washington, has experimented in air with tubes of the type devised by me, and compared the results obtained from the Pitot tube with practically exact results obtained independently. He found the Pitot tube results agreed very closely indeed with the results of the accurate independent observations, and there seems no doubt that a properly shaped Pitot tube is a very accurate appliance for measuring velocity and pressure of moving air.

Reference is also made to important experiments conducted by Mr. Richard Threlfall and described in a paper read before the English Institution of Mechanical Engineers in 1904, in which measurement was made of the velocities of gases in pipes. From the results of his experiments he concluded that the constant of the tubes was practically unity, that the radius of the circle of mean velocity was about 77.5% of the radius of the pipe, and that the ratio of mean to center velocity was constant over a wide range of velocities, the average value being .873. These results are quite accordant with the data obtained in the present investigation.

The use of the Pitot tube as a means of measuring the velocity of flowing water has been the subject of much investigation, and there should be little doubt remaining as to the accuracy of its indications when used for that purpose. The tube described in this paper has been experimented with, to some extent, by the writer, in connection with the measurement of water flowing through pipes, under pressures as high as 10 lbs. per sq. in., the results indicating in every case that the theoretical equation $v = \sqrt{2gh}$ holds with liquids as with gases. The discrepancies in the results obtained by many observers have, no doubt, as indicated by Captain Taylor, been due to the aspiration effects of the moving stream on improperly designed pressure tubes, rather than to variation in the construction of the Pitot tube itself.

The following is a partial list of the more important recent contributions to Pitot tube literature, in addition to those noted above:

"The Pitot Tube." W. B. Gregory. Trans. Am. Soc. M. E., 1904, p. 184.

"Experimental Study of the Resistance of the Flow of Water in Pipes." By A. V. Saph and E. W. Schoder, Proc. Am. Soc. C. E., May, 1903.

"Resistance of Plane Surfaces in a Uniform Current of Air," by T. E. Stanton, Collected Researches, National Physical Laboratory (Great Britain), Vol. 1, p. 245.

"Experiments on the Effect of Curvature on the Flow of Water in Pipes," by G. S. Williams, C. W. Hubbell and G. H. Fenkel, Proc. Am. Soc. C. E., Sept., 1901.

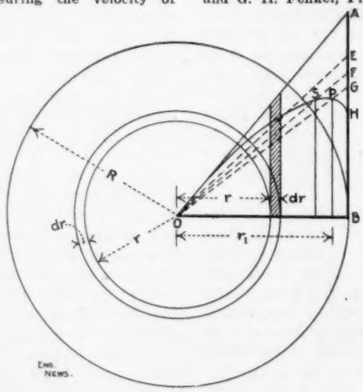

Fig. 2.

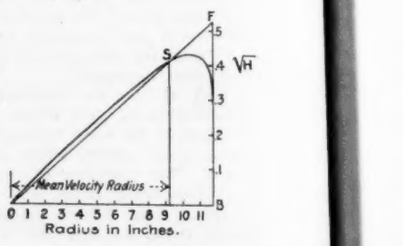

Fig. 3.

FIGS. 2 AND 3. DIAGRAMS ILLUSTRATING METHOD OF DEDUCING MEAN VELOCITIES FROM PITOT TUBE READINGS.

"Tests of Centrifugal Pumps," W. B. Gregory, Trans. Am. Soc. M. E., 1901, p. 262.

"Heating and Ventilating Buildings," R. C. Carpenter, Chap. 2.

"Pitot Tubes, with Experimental Study of the Form and Velocity of Jets," by J. E. Boyd and Horace Judd, Eng. News, March 31, 1904, p. 318.

Am. Gas Light Journal, W. A. Baehr, April 18, 1904, p. 605.

*Van Nostrand's Engineering Magazine, 1886, p. 91.
†Geological Survey of Ohio, 1888, Vol. 6, p. 548.
‡Trans. Am. Soc. M. E., 1904, Vol. 25, p. 208.

*Engineering News, Nov. 3, 1904.
†Journal Assoc. Eng. Soc., August, 1901.

TABLE II.—Summary of Results obtained with Pitot Tube on Gas Main During Six Runs.

Number of run.	1	2	3	4	5	6
Temperature gas, Deg. F.	59.0	61.0	64.0	60.0	67.0	60.0
Barometric pressure, ins. mercury	29.22	29.66	29.22	29.66	29.48	29.6
Pressure in holder, ins. water	5.32	5.3	4.11	5.33	5.32	4.11
Pressure in pipe, ins. water	5.65	5.65	4.52	6.13	5.41	4.11
Weight of 1 cu. ft. gas at temp. and press. in pipe lbs., D	.0483	.0507	.0476	.0508	.0497	.0508
Actual flow of gas reduced to temp. and press. in pipe, cu. ft. per sec.	106.3	125.6	132.4	173.2	177.8	200.5
Corresponding mean velocity, ft. per sec.	34.5	40.7	43.0	56.2	57.7	65.1
Velocity at center of pipe according to pitot tube, ft. per sec.	40.2	47.45	49.9	63.55	66.3	72.5
Mean velocity as determined from Pitot tube readings, ft. per sec.	34.4	40.4	43.0	56.5	57.2	64.6
Ratio of mean velocity to velocity at center	.857	.851	.862	.889	.863	.891
Mean-velocity radius, ins.	9.24	8.94	9.20	8.94	8.84	8.69
Value of the constant, K, in formula, $V = K\sqrt{2gh}$	1.001	1.007	1.000	.994	1.008	1.009

THE TRIANGULATION AND CONSTRUCTION SURVEY FOR THE SIMPLON TUNNEL.

By Horace Andrews,* M. Am. Soc. C. E.

The nearly completed railway tunnel between Switzerland and Italy under the Simplon Pass is an object of some interest to the surveyor in its quality of the world's longest tunnel. The triangulation which preceded the tunneling operations and controlled their progress was in itself an operation of magnitude and delicacy, as may be appreciated from the statement that the tunnel is 12¼ miles long between portals and that the line of precise-levels between the end survey stations was nearly 30 miles long. The prolongation of the line, during the tunnel work, also involved high precision, but the unfavorable conditions in the tunnel—high temperature, excessive humidity, air currents, and a stratification which produced strong refraction effects—should be taken into account in measuring the precision by the results obtained. The following summary of the

*125 Lancaster St., Albany, N. Y.

work involved in the triangulation and the construction-surveys should therefore be of value, especially as the results of the closure observations, made after the meeting of the headings from the north and south, are now available, and give an indication of the care and precision with which the surveys were conducted.

The triangulation work for the Simplon tunnel was beset with difficulties similar to those met with in the case of the St. Gotthard tunnel. In both instances it was impossible to see from any one central point the two ends of the tunnel, or, to speak more strictly, the survey observatories established on the axis of the tunnel outside the end portals. In the case of the Mt. Cenis tunnel, the third of the existing great railway tunnels through the Alps, such a central point could be found, and the problem was therefore much simplified.

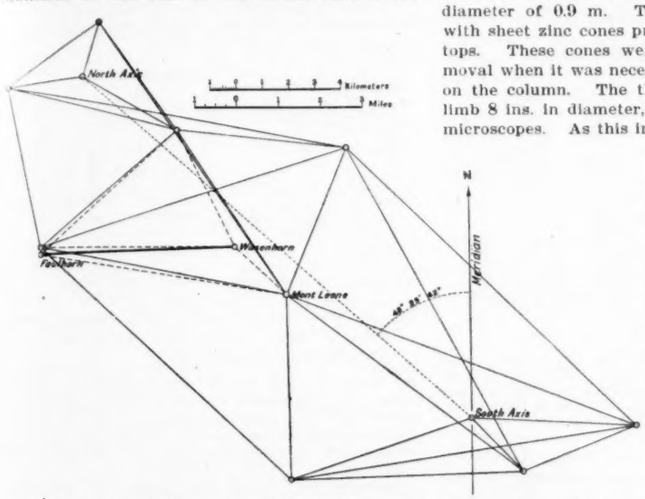

FIG. 1. DIAGRAM OF TRIANGULATION NET WORK FOR THE CONSTRUCTION-SURVEYS OF THE SIMPLON TUNNEL.

The Simplon tunnel is a tangent about 12 miles 27 ft. long, with a curve at each entrance. As the great length of the tunnel rendered high accuracy in the alinement imperative, short headings were driven at both ends, in prolongation of the axis of the tangent, to give a direct line of sight from the triangulation stations outside. These headings aggregate 1,338 ft. in length; they measure 6.5 × 6.5 ft. in cross section and have a flat arch roof.

The main tunnel, or rather the pair of parallel tunnels, 17 meters apart between axes, has already been described in Engineering News, in the issues of Aug. 13 and 20, 1903, and a topographical map is given on page 389 for Nov. 1, 1890. The northeasterly of the two tunnels, known as tunnel No. 1, is now completed (see Fig. 2 herewith for a cross-section diagram), and these notes relating to the alinement refer to this tunnel.

A sketch of the trigonometrical net is shown in Fig. 1. The following objects were sought in the scheme: 1. Each of the two tunnel axis-points was to be connected with no less than three trigonometrical stations, with directions differing from one another as much as possible.

2. The number of stations was to be as small as possible.

3. In order to obtain perfect checks, the triangulation-net was to be a double one, each part capable of giving the desired results, while both were to be united by cross lines, tying the two systems together.

4. To obtain a basis for the correct length and azimuth of the tunnel's axis the trigonometrical net was to be connected with the geodetic net of the Swiss precise triangulation (in place of using an independent base line, which would require high-precision base measurements).

In utilizing the existing government triangulation, allowance had to be made for the tunnel's elevation of 633 meters above the sea level, for the sides of the Federal triangulation are reduced to sea level, as usual. This correction in the computed length of the tunnel as derived from the triangulation would be very nearly two meters in amount.*

Including the two axis stations the trigonometrical net of the Simplon tunnel comprised eleven angle points in addition to the two points "Wasenhorn" and "Faulhorn" of the geodetic net. The highest station, Mt. Leone, is 11,670 ft. above the sea; the lowest, that at the south axis, 2,076 ft. The last mentioned point lies in a deep ravine, rendering its trigonometrical connection a difficult problem. The stations were marked with masonry columns carried 1 m. above the ground with a minimum diameter of ½ m. These had foundations of masonry extending 1 m. in depth and of a diameter of 0.9 m. The columns were capped with sheet zinc cones projecting 2 ft. above their tops. These cones were arranged for easy removal when it was necessary to set the theodolite on the column. The theodolite employed had a limb 8 ins. in diameter, reading with micrometer microscopes. As this instrument was injured before the work was completed, a 9-in. vernier instrument was used at two of the stations. All directions were obtained with equal precision by the system of simple angle measurements with the equivalent of 48 measures to each angle. Angles were measured in all possible combinations, so that with three directions each angle had 32 measures, with four directions each angle was measured 24 times, with five directions each had 20 measures, etc.

The triangle closures were found to average 3.1" and to reach a maximum amount of 8.5". New observations made where the apparent errors were the largest led to no explanation of the remarkable errors, so an investigation was made as to the effect of the mountain mass upon the direction of the plumb-line. A deviation of the vertical would have the same effect upon an angular measurement as an error in leveling the limb, and would only become apparent where there were very decided angles of elevation, or depression, to one or more of the station marks. By means of a contoured map of the mountains, with an assumed specific gravity of 2.8 for the mountain mass, the amount and direction of the deviation were deduced (see Clarke's Geodesy, p. 295-9), and from the known angles of elevation, corrections were computed for the observed horizontal angles. This theoretical procedure was verified by means of astronomical azimuths at the tunnel's mouths and their comparison as carried through the triangulation. With the reduced angles the average triangle closure was found to be 1.7", while the greatest was 5.0", a much more favorable showing.

The reduced angles were then used in the adjustment of errors throughout the entire net of the triangulation. On account of supernumerary measurements there were 18 unknown quantities to be obtained by the solution of as many normal equations, with 56 equations of error. The probable error in the determination of the tunnel direction was computed to be 0".47, and the mean error of the tunnel length, from the triangulation errors only and disregarding any error existing in the initial base side, was 0.46 ft. When the ± probable error of the initial base, whose length had been taken direct from the government triangulation records, was also taken into consideration the estimated mean error in the tunnel's length was increased to ± 1.84 ft.

For practical purposes only, some of the theoretical refinement could have been dispensed with. To see what effect the corrections due to the plumb-line deflection had upon the final direction of the tunnel's axis, the triangulation was computed with the observed angles, corrected, however, by the least-square adjustment in order that the mathematical conditions might be fulfilled. The two adjustments indicated that a discrepancy of 0.85 ft. in lateral displacement at the junction of the north and south tunnel headings would result, depending upon the use of the angles as observed or as corrected for the local variation of the plumb. The last-named (corrected) angles were employed in the subsequent alinement.

Direction marks visible both by day and by night were carefully placed in the vertical plane passing through the tunnel's axis. For safety these marks were placed in niches that could be locked up. They consisted of iron boxes having slits covered with milk-glass, the widths of the slits being governed by the distances of the boxes from the instrument. With distances of 1,840 and 2,450 ft. on the north end the slits were made about 0.8 in. wide, while upon the steep sides of the narrow valley at the south end, with distances of 302 and 174 ft. only, the slits were accordingly narrowed to 0.08 in.

After points had been lined in at about 1,640 ft. within the tunnel at each end, they, and the direction marks from which they were derived, were tested by measuring angles between them and the trigonometrical stations visible from the portal observatories. This procedure being repeated at different times of the year indicated slight angular changes due to lateral refraction; the changes amounted to four or five seconds at the south end, both the direction marks outside and the tunnel marks within being almost equally affected. In order, therefore, to check the position of the marks which defined the tunnel's axis, a very large number of measurements were made of the angles at different times, 472 upon the north end mark and 384 upon the south end mark. These measurements indicated that the direction marks were placed with satisfactory accuracy.

The prolongation of the line into the tunnel was a simple operation after the marks had been fixed. It was made with a telescope that could be removed from its supports, so that the ends of its axis could be transposed, to eliminate errors of collimation. Acetylene lamps were used in the tunnel with telephonic communication from the instrument. The lamp was on a stand with a movable slit, the position of which could be read on a scale as well as marked graphically on a strip of paper as a check. For this alinement at least eight sights, in both positions of the telescope, were employed.

Very long sights from the observatory were found to be inadvisable on account of the distortion of image caused by the change in refraction when the line of sight entered the tunnel. On the other hand, when the instrument was removed to the interior of the tunnel irregularities of image were found to be comparatively small. On account of the excellent ventilation the lamp signals could be used even at distances of 2½ miles. However, occasionally serious difficulty was caused in the alinement work by *variable* refraction within the tunnel. Thus, at times when a backsight was being taken in the tunnel the back lamp would appear to creep slowly but constantly to one side, in one case a distance of ¾-in. during 16 successive reversals, with sights about 1½ miles long. The influence of such effects, as well as of possible movements in the tunnel floor, as noted below, would undoubtedly add to the probable errors normally inherent in the survey work.

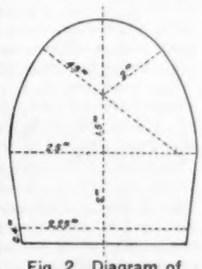

Fig. 2. Diagram of Cross-Section of Finished Tunnel.

The alinement prolongation showed a probable error, computed from the differences of the individual settings, of 0.15 in. per mile, or about 1 in. for the half length of the tunnel. The total probable error in alinement was, therefore, compounded of the probable error of 2 ins. in the triangulation (corresponding to the probable error of

*A similar correction would be needed if our own government triangulation should be utilized for any refined measurements at a place where the elevation of the country is considerable.

0".47 in the determination of the angles), and 1 in. each from the tunnel prolongation in the two ends, and amounted to

$$\pm \sqrt{2^2 + 1^2 + 1^2} = \pm 2.4 \text{ ins.} = \pm 0.2 \text{ ft.}$$

The actual error of closure, 0.663 ft., as given in the tabulation farther on, is several times greater. The discrepancy may reasonably be charged to the irregular influences above noted.

The elevations and grades of the tunnel were based on two lines of precise-levels run between Brig and Iselle over the Simplon Pass in 1870 and 1873. The two lines differed by 0.380 ft., the lines being 29 miles long each; their average was taken as the basis for the elevations of the tunnel portals. The figure of 0.087 m., given below, as the error of closure in level, is based on these elevations. Check levels were run over parts of the precise-level line in 1898 to 1900, which (themselves affected with a probable error of about 0.025 m. = 0.08 ft.) showed the original levels to be about 0.061 m. (0.200 ft.) in error; this result was not applied to the tunnel elevations, to avoid confusion in the records. It increases the actual error of closure to 0.148 m. (0.485 ft.), which corresponds to an average error, on 12¼ miles, of about 1½ to 2 ins. (0.12 to 0.17 ft.) per mile. This error is difficult to explain, as the levels inside the tunnel were run in duplicate, and each line with two rods, giving a double check; the resulting levels never differed more than one or two hundredths of a foot per mile. Most of the length of the tunnel was repeatedly checked in levels, at periods a year or more apart, and these checks showed that various parts of the tunnel apparently shifted in elevation, some sinking, some rising, by amounts up to 21 mm. (0.07 ft.) It is quite possible that the final closure survey, which appears to have covered only the middle 4-mile section, was affected with error by similar movement of its initial and terminal stations since the last determination of these stations.

It is possible, also, that movements of this character affected the alinement closure. In fact, an apparent shifting *within* the 4-mile length in question was observed during the closure survey, one station plug near the center of the tunnel being found to be nearly 7 ins. to the east of the center line.

The measurements of distance, within the tunnel, were made by two methods. The earlier portions of the work were measured with five-meter rods, compared with standards before and after each set of measurements. As this method was too slow and required a large force, however, the later measurements were made by a wheel of 3 m. circumference, rolled on one rail of the finished track. The first method was sufficiently accurate to check on two repetitions, by about 0.15 ft. per mile, on the average; the second method taking the average of four repetitions, would contain a probable error of about 0.50 ft. per mile.

The probable error of the triangulation, combined with the probable error of the Federal line Wasenhorn-Faulhorn, gives, as already stated, a mean probable error of ± 1.84 ft. in length, in the tunnel axis. The measurements within the tunnel would contribute an error of about the same order, so that a total mean probable error approximating 1 m. might be expected. The actual closure survey when the headings met showed a discrepancy of 0.79 m., or 2.59 ft., which is thus well accounted for by the conditions of the survey work.

The triangulation was carried out in the summer of 1898. The primary surveys of alinement, level and distance in the tunnel were made at regular intervals, at first every six months and later yearly; such work consumed from 24 to 32 hrs. on each occasion, during which period all construction work in the tunnel was stopped. Besides these principal stakings-out, subordinate measurements were, as a matter of course, made continually.

Most of the details outlined in the above were described in a published article by Prof. M. Rosenmund, of Zürich, who conducted the work, in February, 1902. A special report upon the subject was made to the Department of Railroads of Switzerland, in 1901. Dr. Paul Gast published in 1904 an extended account of his observations relative to the peculiar phenomena due to refraction observed by him, and which were responsible for the abandonment of the original plan of prolonging the alinement entirely from the fixed observatories, even to the point of junction.

Quite recently Prof. Rosenmund, in a paper* before the Schweizerische Ingenieur und Architekten Verein, has given a statement of the results of the final closure measurements made after the meeting of the headings, which he prefaced by an analysis of the sources of error in the work, as given in abstract in the present article.

The check measurements were made on August 14 and 15, 1905. Although the rock between the headings was pierced on Feb. 24 of this year, the junction of the headings over the full section was not accomplished for several months later. Even then there remained a serious obstacle to the check survey, in the shape of thick fog in the section near the junction point, produced by large hot springs at this point. The results of the measurements are:

Lateral divergence between the tunnel axes as prolonged from the two ends respectively	0.202 m. = 0.663 ft.
Difference in elevation of a bench-mark in the tunnel as determined by leveling from the two ends respectively	0.087 m.† = 0.285 ft.
Distance between end stations by triangulation	19756.31 m.
By measurement through tunnel	19755.52 m.
Difference in distance	0.79 m. = 2.59 ft.

†Referred to precise-levels run over the Simplon Pass in 1870 and 1873. Later levels, as noted in the text of this article, increase the error of closure to 0.148 m. = 0.485 ft.

It is not known to the writer that any investigations were made regarding the effect of the mountain mass upon the leveling operations, though there should be an appreciable difference, due to this cause, between leveling over the mountains and through the tunnel.

REPORT OF A TEST ON A PORTLAND CEMENT PLANT.†

By E. C. Soper.‡

The Germans were the first to investigate thoroughly the subject and to produce Portland cement as a commercial article, and in consequence the industry has grown in that country to such an extent that at the present time an over production exists. In the original plants, in fact in 80% of the present plants of Europe, vertical kilns were and are used. The first plants built in the United States were duplicates of the German plants, but because of the high price of labor and the low price of fuel in this country, as compared with the prevailing conditions in Europe, it was necessary for the Americans to perfect the German system. The most marked change which resulted was the substitution of the rotary kiln for the vertical kiln.

During the last few years every department in the manufacture of cement has received the attention of engineers, and in many instances valuable improvements have been made, but the one stage which has probably received the most attention, and which will still admit of further improvement is the process of burning or clinkering.

Rotary kilns have been designed and built, varying in length from 60 ft. to 150 ft., and with a diameter of from 4 ft. to 8 ft. It has been fully demonstrated that the 60 ft. kilns require more fuel per barrel of cement, whether coal, gas or oil be used as fuel, than the 100 ft. kiln. The capacity has increased and the fuel consumption decreased with the increase of the diameter of the kilns within certain limits.

By repeated experiments and calculations we have determined that this proper length is from 100 ft. to 125 ft. and a diameter from 7 ft. to 9 ft., and that the straight kiln produces from 20% to 30% more clinker than the tapered or bottle neck kiln. In actual practice, in the same plants, working on the same materials, using the same fuel and under the same conditions, these statements have been verified.

A 60 ft. by 6 ft. kiln, which was the standard up to two years ago, working on the dry process and under ideal conditions, will produce on an average 175 to 200 barrels per day, and at a fuel consumption of 130 lbs. of coal per barrel of clinker burned. A 100 ft. kiln of 7 ft. diameter, working on the same material, will produce 225 to 250 barrels per day, with 100 lbs. of coal per barrel. Of course different materials vary in their burning qualities and are affected considerably by weather conditions. These and many other conditions must be taken into consideration in comparing the results obtained with rotary kilns.

*Reprinted in the "Schweizerische Bauzeitung" of Sept. 9, 1905.

†Abstract of paper before the Western Society of Engineers, Nov. 15, 1905.

‡Hunt Engineering Co., Iola, Kan.

OBSERVATIONS ON THE OPERATION OF A ROTARY KILN.

The primary object of the following tests was to determine the value in point of cost of operation, fuel consumption per barrel, output per kiln, and in fact the value of the long kiln to the industry in general, and in particular, to the plant in question. The tests were made Aug. 31, 1905, by members of the engineering staff of the Hunt Engineering Co., of Iola, Kansas, who rebuilt the plant and installed the long kilns, utilizing the old vertical kilns for clinker pits and coolers.

In order to determine the actual temperature at various points throughout the length of the kiln, which to

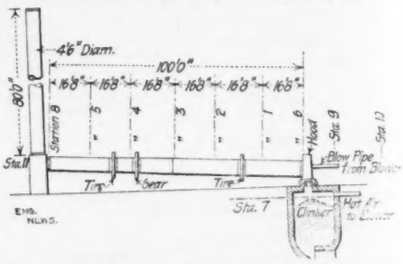

Fig. 1. Sketch of 100 × 6 × 7 Ft. Rotary Cement Kiln, Showing Positions of Pyrometers Used in Determining Temperatures.

our knowledge had never been accomplished, several holes were drilled through the kiln shell and brick lining, as shown on sketch of kiln, Fig. 1. A LeChatelier electrical pyrometer was used for determining the higher temperatures, 1° Fahrenheit being equivalent to 0.0001 volts.

Readings were taken at each station every 10 seconds where the heat was intense, and every 30 seconds where there was slight danger of melting the porcelain tube. The readings were noted so long as there was a marked rise in temperature, or when the curve became parallel to the Y-axis, and Fig. 2 is the curve of the maximum temperature observed. The exact temperature at station 1 of of 2,496° F. is the temperature of the clinker itself and 2,587° F. is the temperature of the gases.

When designing the plant, the length of the kiln was calculated so as to give a stack temperature of about 400° F. operating on the materials in question. This length was determined at 100 ft. and in actual practice and operation the waste gases had a temperature of 456° F.

CONDITIONS.

To produce one barrel of cement of 384 lbs., there is required 1,319 lbs. of slurry, containing 53% or 699 lbs. of water, which has to be evaporated, leaving 620 lbs. of dry mixture.

With an output of 166 barrels of cement per day of 24 hours, this is equal to 6.9 barrels per hour, and the time required to burn or clinker one barrel of cement is 0.145 of an hour. There is actually required 180 lbs.

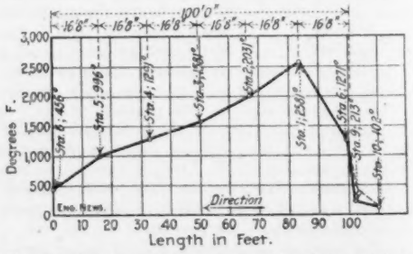

Fig. 2. Maximum Temperatures in Rotary Kiln as Shown by Pyrometer Readings.

of coal to burn one barrel of cement. The kiln is 100 ft. long and 6 ft. to 7 ft. in diameter; is rotated at a speed of 1 revolution in 2 minutes, driven by a 15 HP. motor. The stack is 4 ft. 6 ins. in diameter by 80 ft. high.

The proximate analysis of the Iowa coal is:

Volatile matter	43.30%
Fixed carbon	30.98%
Ash	19.56%
Sulphur	6.56%

By calculation from this analysis the heat value of this coal is taken at 10094 B. T. U.

Analysis of the cement material:

RAW MIXTURE.

$CaCO_3$	74.46%
CaO (calculated)	41.36%
Insoluble	19.50%
Sulphur	6.00%
Ignition loss	33.14%

CEMENT.

CaO	64.75%
SiO_2	19.75%
Fe_2O_3	6.25%
Al_2O_3	6.50%
Mg. O	.80%
SO_3	1.90%

TEMPERATURES OBSERVED.

Air entering kiln from blower	213° F.
Air surrounding the kiln	102° F.
Slurry	95° F.
Average of the kiln shell	280° F.
Clinker, falling from the hood	1,381° F.
Waste gases entering the stack	456° F.
Clinkering zone	2,496° F.

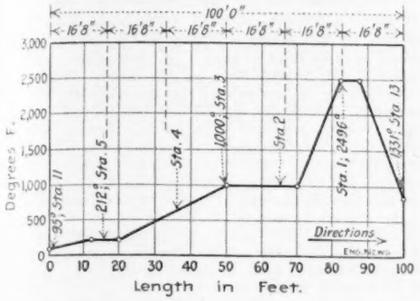

Fig. 3. Maximum Temperatures of Kiln Materials Determined from Recorded Gas Temperatures.

(Temperatures at Stations 1, 11 and 12 actually observed.)

DISTRIBUTION OF HEAT PER BARREL OF CEMENT.

1. Evaporation and heating of 699 lbs. of water to 456° F. waste gases temperature	838,883 B. T. U.
2. In the dry mixture, of 620 lbs., with 461.7 lbs. CaO_2 to be decomposed.	353,200 B. T. U.
3. With 37.2 lbs. SO_3 to be liberated...	70,308 B. T. U.
4. With 620 lbs. dry mixture, heated from 95° F. to 1,000° F. (CO_2 reduced)	112,220 B. T. U.
5. With 384 lbs. of clinker heated from 1,000° F. to 2,496° F.	147,856 B. T. U.
6. With 384 lbs. of clinker discharged at 1,361° F. into the air at 213° F. the loss is	107,835 B. T. U.
7. Loss by radiation from 2,042 sq. ft. surface of kiln and 66 sq. ft. of hood, reduced to the unit of one barrel of cement, equals	201,256 B. T. U.
8. Heating up of air blown into the furnace with a pressure of 5.75 ins. of water and with 3 ins. diameter of nozzle, amounting to 3,878.5 cu. ft. of air per barrel of cement burned, amounts to	6,040 B. T. U.
The combustion of Iowa coal (analysis given) requires about 8 lbs. of air per lb. of coal (theoretical), and allowing 50% excess of air, the consumption of 180 lbs. of coal per barrel of cement requires 2,160 lbs. of air.	
9. Loss of heat by the waste gases at a temperature of 456° F. and of 2,160 lbs. of air heated from 102° F. amounts to	175,824 B. T. U.

With the old kiln of 60 ft. length the waste of heat by higher temperature of waste gases (item 9), greater loss of heat in the clinker (item 6) and greater loss in evaporation and heating of the water (item 1) amounts to a saving, with the 100 ft. kiln, of 483,126 B. T. U., which is equivalent, under ordinary operating conditions, to about 48 lbs. of coal per barrel of cement.

Further improvement can be effected by having the slurry of a temperature of 200° F. (item 1)—a saving of 73,194 B. T. U.; by using the air of a temperature of 450° F. (item 6)—a saving of 22,011 B. T. U.; by the saving of a mederate stack temperature (item 9), 123,120 B. T. U.

The total saving, with these improvements, using the 100 ft. kiln shown, as against the old 60 ft. kiln, amounts to 701,451 B. T. U., equivalent to about 72 lbs. of coal, operating under ordinary conditions.

HEAT SUPPLIED THE KILN PER BARREL OF CEMENT.

10. Heat produced by chemical reactions; from the line (CaO) and magnesia (Mg O); from 248.64 lbs. CaO per barrel of clinker there is liberated 237,164 B. T. U.; from 3.4 lbs. Mg O per barrel of clinker there is liberated 5,061 B. T. U., a total by chemical reaction of	242,225 B. T. U.
11. From the air entering the kiln through coal feeder blow pipe....	6,040 B. T. U.
12. From the gases (CO_2 and SO_3) reduced from 1,000° F. to 456° F. there are	26,625 B. T. U.
13. Heat from the combustion of 180 lbs. of the Iowa coal, of a thermic value of 10,094 B. T. U. on the assumption that 1.5 times the theoretical quantity of air is supplied for combustion, the heat used amounts to, per barrel of cement	1,755,720 B. T. U.
The total of these four items is...	2,030,610 B. T. U.

RECAPITULATION, DISTRIBUTION OF HEAT IN KILN PER BARREL OF CEMENT.

1. Evaporation of water	838,883 B. T. U.
2. Carbonate of lime, decomposed....	353,200 B. T. U.
3. Sulphuric anhydride liberated	70,308 B. T. U.
4. Dry mixture heated to 1,000° F....	112,220 B. T. U.
5. Clinker heated to 2,496° F.....	147,856 B. T. U.
6. Clinker discharged at 1,391° F....	107,835 B. T. U.
7. Radiation losses, kiln and hood ...	201,256 B. T. U.
9. Heat loss in waste gases	175,824 B. T. U.
Total of these items	2,007,382 B. T. U.
But the total heat, per barrel of cement supplied the kiln, items 10, 11, 12 and 13 is	2,030,610 B. T. U.
and the difference unaccounted for is..	23,228 B. T. U.

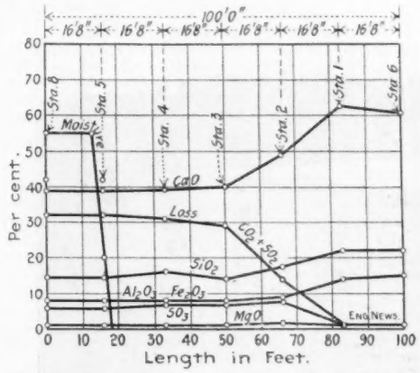

Fig. 4. Diagrams Showing Changes in Chemical Composition of Clinker at Different Points in the Length of the Kiln.

If Fairmount coal from West Virginia be used, with a proximate analysis of

Fixed carbon	53.24%
Volatile	38.10%
Ash	8.06%
Sulphur	.75%

the thermic value, based on this analysis, is 12,411 B. T. U.

The amount of this coal required to burn one barrel of cement is 146 lbs.

The Iowa coal has ash, of 19.16%, with about the following composition, SiO_2—5%, Fe_2O_3—10%, and Al_2O_3—4%, which accounts for the higher percentage of silica, iron and alumina in the finished product than would occur if a coal was used with a lower content of ash.

OPINION.

Assuming that certain further improvements and alterations be effected as recommended, then a further saving in the 218,325 B. T. U., of the present installation, can be made, equivalent to 22 lbs. of the "Iowa Stock" coal, which will reduce the coal consumption per barrel to 158 lbs. For the sake of comparison, if Fairmount (West Virginia) coal be considered, then this reduction would be equivalent to 18 lbs., or 128 lbs. of coal per barrel of cement burned; this is believed to be as low as it can be reduced without the installation of complicated and costly apparatus, whose utility and practicability are still to be demonstrated.

The stack gases are as low in temperature as is consistent for good draft without mechanical means. To prove the results actually obtained are as satisfactory in point of economy and cost as could be obtained through the use of the system as installed by Prof. Carpenter at Cayuga Lake (which consisted of passing the waste gases from a 60 ft. kiln to the grates of boilers, and thus conserving the heat, otherwise wasted, for power purposes) the following calculations are given:

From the curve sheet No. 8 estimate approximately the temperature of a 60 ft. kiln, operating under similar conditions to those in this test. At 50 ft. (station 3) the gases in the kiln are at 1,581° F. and at station 4, 66 ft. 8 in. from the furnace end of the kiln, they are 1,291° F., so it may be assumed that at 60 ft. the temperature is 1,400° F.

However, in a 60 ft. kiln, operating on the wet process, these gases are seldom above 1,000° to 1,200° F., and assuming them at 1,000° F. to conform to the foregoing calculations, the 100 ft. kiln effects at the present time a saving over the 60 ft. kiln of 50 lbs. of coal per barrel of cement.

Then with waste gases at 1,000° F. they will carry under the boiler the following heat units: In the case of the coal in question, 2,160 lbs. of air are required to burn one barrel of cement, and the waste gases hold 446,040 B. T. U.

Assuming a boiler efficiency of 70%, then these 446,040 B. T. U. become 312,228 B. T. U. actually converted into steam for power purposes, which is equivalent to 32 lbs. of coal saved per barrel of cement, by utilizing the stack gases from a 60 ft. kiln operating on the "wet process."

But the long kiln, besides being a much simpler installation and less costly, has an advantage of 18 lbs. of coal per barrel of clinker burned. The long kiln will be in practically continuous operation, while in the case of the waste-gas boiler installation, the one must necessarily depend, to a certain extent, upon the other, in their operation.

ANALYSIS OF SAMPLES.

If a study is made of comparison of action throughout the length of the kiln, of curve Fig. 3, it will be noticed for the first 50 ft. there is comparatively no change in the sulphur, silica, magnesia, alumina and iron contents. The moisture is driven off so that at station No. 5 the material was practically bone dry. The CO_2 began to be driven off between station 5 and 4, slowly, but starting at the middle of the kiln (station 3) it dropped rapidly for the next 33 ft. In plotting the curve of maximum temperatures of materials, curve Fig. 4, it is assumed that the CO_2 is driven off where the temperature of the material is 1,000° F. as the temperature of the gases at this point (station 3) is 1,500° F. and beginning at this point, referring to the comparison curves of analysis, the CO_2 is rapidly driven off, but the ... is driven off between stations 2 and 1.

Then the probable action in the materials is this; the material is heated from its entering temperature to 212° F. where the water is converted into steam, and during this process, the temperature remains constant; then the temperature rises gradually to 1,000° F., where the CO_2 is given off and the temperature again remaining constant, but rises rapidly after this action to the clinkering temperature of 2,496° F. Here the temperature probably remains constant a short time, and then decreases rapidly as the cooler entering gases strike it.

The temperature of the gases as plotted on curve sheet No. 8 is accurate within the limits of the pyrometer. A point worth mentioning is that in reconstructing this plant use was made of the old vertical kilns for clinker pits, as shown in sketch of kiln. The plant before reconstructing was not a paying proposition financially, because of the high cost of coke (from $8 to $11 per ton), and cost of labor due to the old methods employed. But by the installation of the long kiln, the use of Iowa slack coal at a cost of $2.60 per ton and containing a high percentage of ash and sulphur, can be used. The sulphur in the raw mixtures, as will be noticed from the curve, is about 7% and is reduced to 1.78% in the clinker. The manufacturing cost per barrel has been reduced to one-half the original amount.

THE IMPORTANCE OF FIRE DRILL FOR THE SAFETY OF OPERATIVES IN MANUFACTURING PLANTS.*

By H. F. J. Porter,† M. Am. Soc. M. E.

The tendency in building construction nowadays is manifestly in the direction of fireproof construction. It will, however, be many years before all factories will be fireproof and meantime it becomes necessary to consider the best means to protect the lives and property housed in such factories as now exist. A moral responsibility rests upon the employer of labor. And it is evidently to his interest to enable a prompt escape from the building in case of fire, for it is the first duty of a fire department to save lives before attempting to save property and in a case where lives are in jeopardy attention must first be directed to their relief and meantime much property may be destroyed.

In this connection experience shows that there are more casualties resulting from panic occurring during fire than from the fire itself and also that panic frequently occurs simply on the alarm of fire when actually no fire exists and on other occasions when there is a similar suggestion of danger.

In the ordinary factory we find fire buckets, in many of them stand pipes with hose attached, and in some of them sprinkler systems. But the factories are few which have assigned the duty to certain specified individuals to use the buckets or the hose in case of fire or to turn off the sprinkler system after the fire is out. All of these appliances can, however, become effective by the development of a regular fire corps.

The fire escapes which are supplied to buildings generally are of such construction as to be a more prolific source of than escape from accident. They generally consist of an iron balcony on the outside of the building at each floor, and these balconies are connected by means of ladders, the lowest balcony having its ladder detached and hung up on the building so as to prevent people from entering the building, as they might if it was permanently placed on the ground.

These ladders vary in position from the vertical to an angle of 50° or 60° with the horizontal, and in order to descend people have to turn around and go down backwards. In all cases of emergency when both women and men have to descend by such means and especially in winter weather when the iron is cold and perhaps covered with snow or ice, these so-called escapes are prolific sources of accident, especially at the lowest balcony, where, if the ladder is a long one, it is correspondingly heavy and the combined strength of several

*From a discussion presented at the New York Meeting of the American Society of Mechanical Engineers.

†Consulting Engineer, 1 Madison Ave., New York City.

men is necessary to handle it. These men are not necessarily the first to reach the spot where it is located, and they cannot well get there after others have crowded down ahead of them. There results on such occasions a jam, accompanied by a crowding off of the balcony those who are near the opening.

The fire department of New York City advises me that almost daily they have a fire in a factory where they have to save lives before they can direct their attention to extinguishing flames.

In a factory where I was engaged a couple of years ago, finding the conditions such that in case of fire either within the building or in adjacent buildings, it would be necessary to promptly empty the building of its occupants, I established a fire drill which, by occasional repetition, reduced the time of exit from more than seven to less than three minutes. At first such a drill, owing to its association with danger, is usually accompanied by the fainting of some of the girl employees, later a habit of prompt and rapid dismissal is acquired, and all become possessed with a feeling of security which largely counteracts the tendency towards a panic.

I have examined many factories at the request of the proprietors, to satisfy them that they were doing all they could for the safety of their employees, and I have failed to find any which in one way or another had not introduced some obstruction to the availability of their fire escapes.

Many factories give no thought to the subject after the fire escapes and fire buckets are supplied, and on one occasion the question to the superintendent, what he would do in case a fire occurred right then, was met by the amazing reply that he would think of some way to get his employees out. When pressed to think then, while he had plenty of time, of a way to do this he was utterly unable to say how under conditions as they existed he would have gotten them out.

It is only by going through the manœuvres which would occur in case of an actual fire that the efficiency of the appliances and escapes can be tested. A fire drill will do this, and once introduced its desirability is too evident to allow it to be discontinued.

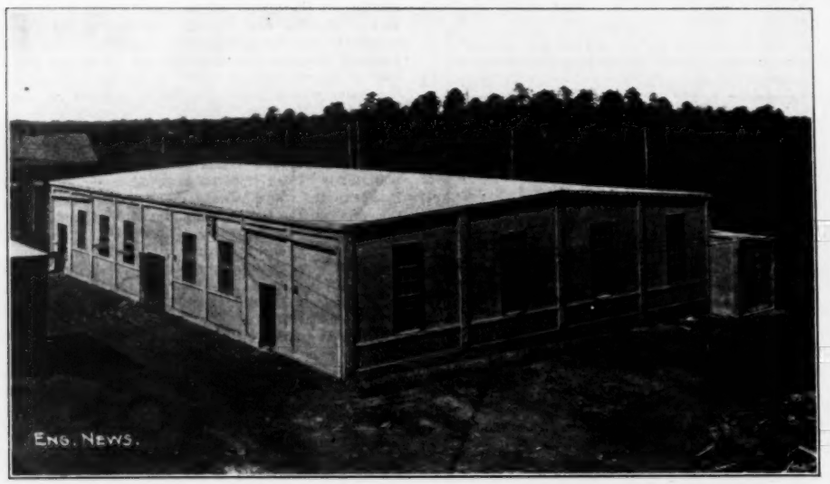

FIG. 1. REINFORCED CONCRETE COTTON MATTRESS FACTORY AT CHARLOTTE, N. C.

A SMALL FACTORY BUILDING OF REINFORCED CONCRETE.

A neat example of the application of reinforced concrete in the construction of small factory buildings is shown by the accompanying cuts. The building illustrated is to be used for the manufacture of cotton mattresses, and reinforced concrete was selected for its construction because of its fire-resisting qualities and for sanitary reasons. It is located at Charlotte, N. C., and is owned by the Southern Cotton Oil Co. Mr. Wayne Cunningham, of Savannah, Ga., was the engineer and contractor, and we are indebted to him for the following account of the work.

The building is 90 ft. long × 60 ft. wide × 15 ft. high to the eaves. It is built of reinforced concrete throughout. The walls from the footing course to the water-table are plain concrete, 12 ins. thick. From the water-table the walls are 6 ins. thick, reinforced both vertically and horizontally with commercial round bars. In the side walls are 12 × 12-in. pilasters, spaced 10 ft. c. to c., and reinforced with Kahn trussed bars in the four corners. In the end walls are 12 × 12-in. pilasters, spaced 15 ft. c. to c. These end pilasters, as well as the four corner pilasters, are without reinforcement. Through the center of the building from end to end there are 10-in. × 12-in. columns, spaced 10 ft. c. to c., which are also reinforced with Kahn bars in the four corners. These center columns and the side wall pilasters support the roof beams, which in turn support the 4-in. roof slab.

There are two toilet rooms connected with the building, one at each end. These toilet rooms are built of reinforced concrete throughout, and the reinforcement throughout is round commercial bars. One of these toilet rooms will be seen in the picture of the finished building in the right-hand corner, Fig. 1.

The floor in the building as originally constructed was a top coat of cement mortar as a concrete base, but after the construction of the floor it was considered by the Southern Cotton Oil Co. expedient to cover the concrete with a wooden floor. The reason for doing this was on account of the possible dampness coupled with the fact that amongst the employees in the building there are a number of women who operate sewing machines.

One side of the building is situated near the property line of the Southern Cotton Oil Co.'s plant, and on which side there is no exposure to fire. This side of the building is equipped with ordinary wood frame and glass windows. The other three sides of the building are equi[pped] with steel frame and wire glass windows.

The view, Fig. 2, shows the building under c[on]struction, and gives a clear idea of the chara[cter] of the forms and the method of handling the m[a]terial. The building was designed by the Trus[ted] Concrete Steel Co., of Detroit, Mich., owner of [the] Kahn Patents for reinforcing concrete.

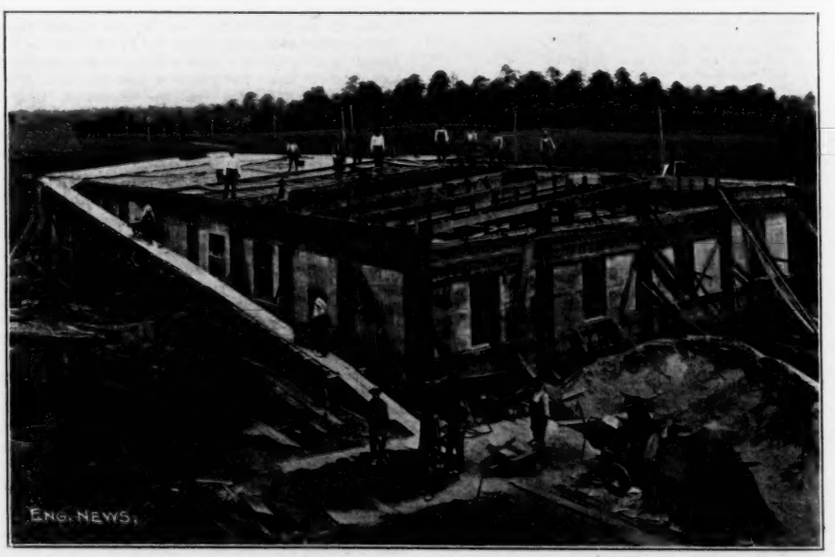

FIG. 2. VIEW OF MATTRESS FACTORY, SHOWING FORMS AND METHOD OF CONSTRUCTION.

NOTES ON SEWAGE DISPOSAL.*

By Baldwin Latham, M. Inst. C. E.

When I first commenced my professional career the question of the disposal of sewage was not considered a matter of any great urgency. At that period, having regard to the investigations and the reports which had been made by the various sanitary commissioners of the unhealthy state of this country generally, it was looked upon as more important to rectify the sanitary defects which led to such an enormous amount of sickness and mortality than to consider the pollution of rivers. The question of the disposal of the sewage so as to avoid the pollution of the streams had rarely been considered. In fact, when the question of sewage disposal first came up it was looked upon rather as a means by which either sewage itself could be applied directly to land or that valuable products might be manufactured from it which would bring in untold wealth.

The passing of the Public Health Act in 1848 was the means of large numbers of works of sewerage being carried out which led to the pollution of the rivers, and which it appeared, from the decisions taken in the law courts, was contrary to the provisions of the common law of England. It was not until the passing of the Rivers Pollution Act of 1865 that it became compulsory to take steps for the purification of sewage.

The late Sir Robert Rawlinson, writing in 1862, said:

> There is at present a great outcry against the pollution of rivers by sewers and the killing of fish. The question may be asked whether it is better to pollute rivers or pollute towns and houses, to kill fish or to kill men? I do not advocate the pollution of rivers, but the application of sewage to land for agricultural uses. If it will not pay as a commercial speculation, make it compulsory and pay the cost by rate. By far the most costly condition in any community is filth in cesspools beneath houses or on the surface around human dwellings.

The processes which have been suggested from time to time for dealing with sewage have been largely composed of chemical or natural processes, or a combination of both. There has been very great conflict of opinion with reference to these processes, as there seems to have been great rivalry among the advocates for each system, which has done much to retard the proper disposal of sewage, and has led to a large amount of loss being sustained by the public in subscribing to the shares of companies or in the payment of public rates.

CHEMICAL PROCESSES.

With regard to the chemical processes for treating sewage, there is hardly a single earthy salt or metallic compound which has not been proposed at some time or other for the purpose of the treatment of sewage

*Abstract of Presidential address delivered before the Association of Managers of Sewage Disposal Works, April 1905. The address in full was printed in the London "Surveyor" for April 21, 28 and May 5, 1905, and "The Public Health Engineer" for April 29 and May 6, 1905.

The earliest chemical process actually used was the lime process; but it should be remembered that lime was first used in Dr. Clark's process for softening water in 1841, and there is a record that when Mr. Arthur Aikin, in 1845, was asked what was the best agent to use for clarifying sewage he stated cream of lime.

Shortly after this Mr. Higgs took out his patent for the lime process for treating sewage in 1846, and Mr. Wickstead had patents for the treatment of sewage by lime and other compounds both in 1851 and 1854, and also for the machinery necessary for dealing with the sewage. Mr. Wickstead carried out very extensive works for a company at Leicester for the purpose of manufacturing a manure, the works alone being reported to cost £50,000, which entailed a considerable loss on the company, and they were ultimately handed over to the Corporation of Leicester. These works were certainly the pioneer works of all subsequent chemical works, as there were two useful inventions brought out upon these Leicester sewage works—namely, the use of the centrifugal drying machine, which is now so largely used for expressing the liquids from solids, and the filter press, by which the sludge from the sewage was at this early period pressed into bricks, known as "Leicester bricks," and were sold in that condition.

In 1853 the lime process was adopted at Croydon, but with no satisfactory results. [The remainder of the chemical section of the paper has been greatly condensed by omitting some of the less significant processes. Ed.]

The alumina processes for the treatment of sewage have been extensively used. The use of alum was a very ancient device for the clarification of impure water, the first process for the actual treating of sewage being that of Henry Stothert, brought out in 1852, treating the sewage by the salts of alumina and charcoal. In 1853 Mr. A. J. Manning brought out the first of a series of patents extending over some years in which alumina was the principal agent used in the purification of sewage. These patents extended from the year 1853 to 1860. The use of crude sulphate of alumina and lime was covered by these patents.

In 1868 the first of a series of patents, known as the A. B. C process, was obtained. In this process a large amount of chemicals are used, and as a precipitating process it has proved to be one of the most satisfactory, although no precipitation process has yet succeeded in removing more than one-half of the organic impurities from sewage.

In 1869 Dr. M. F. Anderson, of Coventry, brought out his patent for the use of crude sulphate of alumina and a small portion of lime applied separately to the sewage, which was the process worked by the General Sewage & Manure Company, who had such great confidence in it, and thought they were going to realize a large income, that they built extensive works for carrying out their process both at Coventry and at Nuneaton, with the result, however, that they never paid a dividend, and the works became the property of the sanitary authorities. The use of alumina or ferric alum is still largely adopted for the purpose of sewage purification, and it has the distinctive merit that it has the power of combining with certain organic substances in solution in the sewage and rendering them insoluble, and so they are precipitated from the sewage.

The use of certain salts of iron has been one of the processes which has been strongly recommended and used from time to time for the purpose of the treatment of sewage. Dover's process was brought out in 1851, and consisted in treating sewage with muriatic acid, chloride of sodium, and protosulphate of iron, and was tried at Croydon. In the year 1859 Messrs. Hoffman and Frankland recommended the persalts of iron as the best practical precipitant for sewage.

The "International" process of sewage treatment consists of the use of ferrozone and subsequent filtering through polarite filters. The process consists—first, in effecting the precipitation of the solids and the deodorization of the supernatant liquid by means of a combination of salts of iron and alumina; and, secondly, the removal of the organic matter in solution and the aëration of the tank effluent by passing it through a specially constructed filter bed of magnetic spongy carbon, now called "Polarite." There is no doubt that these filters will purify the sewage; but the inventors are too sanguine, and give the beds more work than they ought to perform; and the consequence is that they have failed in some places to purify the sewage and have been abandoned.

From time to time a series of processes have been proposed, for the purpose of not only purifying sewage, but also for producing a valuable precipitate which would add very much to the manurial value of the manure produced. So long ago as 1858 Mr. G. L. Blyth, who was the analytical chemist of the General Board of Health, took out a patent for the separation of ammonia from sewage, together with other fertilizing matters, at the same time purifying the sewage so as to render it fit to be poured into the natural drainage channels of the country. This patent was considered of very great importance by some competent authorities, as it is alleged to cover the whole of the ground since occupied by other patentees using phosphates in the treatment of sewage. The process consisted in the employment of soluble or superphosphate of magnesia, which was added to or mixed with the sewage or other fluids, and then precipitating it with lime or other precipitating agent; the idea being that when superphosphate of magnesia was added to the sewage it neutralized the ammonia, forming an insoluble triple phosphate of magnesia and ammonia, which is precipitated or thrown down out of the liquid. [Descriptions of a number of other phosphate processes are omitted—Ed.] These processes all failed, on account of the cost of the precipitating agents used and the low price realized by the sale of the manure.

ELECTRO CHEMICAL PROCESSES.

The use of electricity for the purification of sewage has also been proposed and adopted. In this case, however, the purification is due simply to a salt made in combination with the electrodes used in connection with the sewage purification, the electricity itself having little or nothing to do with actually purifying the sewage. In 1860 a process of this kind was carried out by Mr. Chisholm, at Watford, and in 1887 a similar process was devised by Mr. W. Webster.

We have also had the "Hermite" process, which consists of the electric treatment of liquids containing chlorides, such as sea water, and applying the treated liquid to the sewage. This process was adopted both at Worthing and at Newport, I. W., at the time of the enteric fever epidemics at these places; but it had little or no effect upon the sewage, and none on the epidemic disease. In both places the epidemic was traced to the source of the water supply. The process has been used for the treatment of hospital sewage. The Oxygen Sewage Purification Co. treated sewage with manganate of soda and nitrate of soda, to produce oxidation of the organic compounds. Latterly [within the past year or so—Ed.] we hear of the oxychloride sewage purification process, which is similar to the Hermite process, except that the compound is produced by the electrical decomposition of salt water.

LAND TREATMENT.

From an early period the application of sewage to land has been shown to be successful in purifying sewage, if not always successful from an agricultural, sanitary, or financial point of view. This is very clearly depicted in the case of Croydon, where so many chemical processes have been used for the purpose of attempting to purify the sewage at the main sewage outfall into the river Wandle. [Mr. Latham here sketches the development of the Croydon sewage farms, known as Norwood and Beddington, respectively, and states that he was connected with the early stages of each. He tells how, beginning in 1864, he learned by experience at the Norwood farm that clay lands should not be underdrained, and how engineers and also a committee of the British Association insisted again and again that he did wrong in closing the drains at Norwood. Since then experience elsewhere has confirmed Mr. Latham's conclusions at the Norwood farm to the effect that drains in clay land cause soil shrinkage and the formation of "minute air openings," through which openings the sewage passes to the drains without contact with the soil and hence without purification. The Local Government Board of England has for some time prohibited underdrains in clay sewage farms—Ed.]

INTERMITTENT FILTRATION.

Intermittent filtration is one of the means which have been suggested some years ago by the late Sir Edward Frankland for the purpose of purifying sewage. There is no doubt, from what we know now, that the process of intermittent filtration is one to be highly commended, and possibly I was the first person who carried out any works of this kind with this object, for in August, 1868, I prepared the plans for the works for the St. Ives (Huntingdon) Union workhouse. The workhouse was completely redrained, and the sewage, after being collected in a low-level tank, was pumped every day into a high-level tank, and when this high-level tank had been filled the sewage was flushed on to one or other plots of porous ground prepared for its reception and filtered through it; and in that way the sewage became purified which had hitherto been a very great nuisance to the establishment. It should be observed that the first experiments of the Rivers Pollution Commissioners were commenced on Dec. 14, 1868, but the report did not appear until 1870.

[The classic experiments of Schloesing and Muntz at Paris and Robert Warrington at Rothamstead, England, 1876-8, which established the theory of the nitrifying organism (also suggested by Pasteur in 1862) are here outlined—Ed.]

MR. LATHAM'S CONTROLLED FILTERS.

Having at a very early period received the report of Messrs. Schloesing and Muntz's experiments, the first opportunity I had of putting the method into operation was at Nantwich, in Cheshire, where there are two large tanneries, which turned their refuse into the sewers, which passed into the river and caused serious pollution; and it was determined that the refuse from these tanneries should be purified. For this purpose the tan liquor was treated with salt of iron, to which afterwards the refuse lime water from the tanneries was added. The precipitate was separated by passing the whole of the liquid through a filter-press, and the liquid was passed on to what would now be called bacteriological filters specially made for the purpose of purifying the effluent before it left the tanneries. The filter-beds may be said to be a concentrated land area. I looked upon the surface soils as containing these particular microbes as the only medium of purification, and I put in three distinct layers of sandy surface soil in each filter, separating them by means of burnt ballast, so as to admit the air to each separate layer of soil, with the result that the effluent which passed off these beds had all the appearance of spring water, although containing over 200 grains of solid matter per gallon; the effluent was perfectly innocuous and incapable of undergoing any further change.

After the construction of these filter-beds, in the year 1883, I designed the Friern Barnet filters for the rural sanitary authority, but, owing to delays due to the change of the authority, the actual work of construction of the works did not commence until December, 1885. They were in full operation during the year 1887. The filters I have called controlled bacteriological filters; that is, they consist of a certain amount of surface soil mixed with other ingredients, such as burnt ballast and breeze; and over the top of the filter is placed a thin layer of sandy surface soil, so as to control the rate of filtration. The effect of these filters in purifying the sewage has been marvellous. Similar filters have been made by me at Carshalton, Pontefract, and at Hill End asylum, and in all cases they are found to be most effectual in purifying the sewage when only once passed through the filter, which is a very different state of things to that which is produced in ordinary contact-beds; and even where a filter of this description is used as a contact-bed, the sewage is still forced to filter through the material, so as to produce the purification by filtration rather than by contact, the contact only tending to diminish the amount of air otherwise held by the filter, and consequently diminishes the efficiency of the filter.

A number of analyses of the sewage and effluents from the Friern Barnet sewage works have been made by Mr. R. H. Harland, F. I. C., F. C. S., which show the degree of purification taking place; a sample of sewage and effluent, taken on Sept. 5, 1899, before the addition of contact-beds had been made to these works, gave the result shown in Table I.

It is well known that the State Board of Health of Massachusetts have for a number of years been carrying on most valuable experimental work in connection with the purification of sewage, and they have issued a series of reports; but it should be noted, with reference to these experiments, that they did not begin until January, 1888, and that the Friern Barnet works had actually been at work at least twelve months before the Massachusetts experiments commenced.

Intermittent sand filters have been shown by American experience to be capable of purifying sewage, but as a rule they cannot be operated advantageously at the high rate at which it was once thought would be the case. The results in America show that of the towns which have carried out works the largest number have adopted intermittent sand filtration, while the largest population from which the sewage is treated still carry out chemical precipitation. There is one thing, however, which the Massachusetts experiments show, and that is the rate at which sewage can be purified is in proportion to the inverse relation to the strength of the sewage; that is, the sewage which contains only one-half as much organic matter as another sewage can be filtered under equal conditions at twice the rate of the other sewage, with substantially the same quality of effluent in each case.

CONTACT BEDS AND FILTERS.

The question at the present day arises, which are the best to be used for the purpose of the purification of sewage—contact-beds, that is, beds in which the sewage simply lies in contact with the material, or a filter through which the sewage completely passes, displacing the whole of the sewage which had previously been in the filter?

With regard to contact-beds, of course, if a contact-

TABLE I.—Analyses of Crude Sewage and Effluent from Controlled Filters, Friern Barnet, Sept. 5, 1899. (Grains per [Imp.] Gallon.)

	Crude sewage entering works.	Effluent taken from No. 1 Bed.
Total solid matter	98.7	63.1
Chlorine	9.24	8.17
Equal to sodium chloride	15.22	13.42
Nitrogen as free ammonia	7.8400	.5040
" " albuminoid ammonia	.3584	.0291
" " nitrates	—	3.6400
" " nitrites	f. trace	none
Oxygen absorbed:		
In three minutes at 80° F.	2.415	.084
In four hours at 80° F.	5.066	.357
In four hours after five days' incubation at 80° F. in three minutes	5.705	.070
Suspended matter: Organic	115 10	
Inorganic	29.96	

bed is covered with fine material, and the sewage is passed in from the surface downwards, and the contact material is of a porous character, capable of absorbing sewage, then the sewage being applied on the surface displaces a portion of the sewage held in the material itself, just as in a filter. On the other hand, when the bed is filled up from the bottom there is no doubt that the purification is largely due to the diffusion of the liquid already held in the interstices of the porous material combining with the sewage freshly applied. But if contact-beds are made up of impermeable material, such as flint stones, the degree of purification obtained by contact is very small, and the larger the material the less the purification.

It must be borne in mind that it has been laid down as a regulaton of the Local Government Board that a contact-bed is not to be used more than three times a day. Its capacity is to be estimated at one-third the capacity of the space occupied by the material used. This means that a contact bed will dispose of its whole contents, including the space occupied by materials, once in 24 hours. A contact-bed, 5 ft. deep, will therefore deal with 45 cu. ft., or 281¼ [337 U. S.] gallons, for each superficial yard of filter. The depth of liquid passing through in this case is 60 ins. in 24 hours; and if it was used as a filter, the rate of filtration would be 2½ ins. per hour; but being used as a contact-bed, the rate of contact with the material of the filter becomes much more rapid; and in order to get good results the filter must fill rapidly, so as to enclose as much air as possible in the material of the filter; otherwise, according to experiments which I have conducted, purification is not secured, but anaerobic, instead of aerobic, organisms are developed.

A contact-bed, therefore, should be of such a size that it will fill in ½ hour, the liquid to be purified should remain in contact from 2 to 2½ hours, and 1 hour may be occupied in emptying and draining the bed, leaving 4 hours for aëration. This three times a day, allowing the full time for filling and emptying taken as the time of being in contact, which practically is not the case, the rate of contact in this case with the filtering material is just double that of a continuous filter, or 5 ins. per hour, while the process is proceeding. If, therefore, only half the time of filling and emptying is taken into account, the actual contact is reduced to 3¼ hours each filling or to 9¾ hours in a day, and the rate of contact becomes 6.15 ins. per hour against 2½ ins. per hour in the case of the filter. The rates are not altered if double contact is used, which is absolutely necessary to get purification, as double contact means that the liquid has to pass through double the depth in twice the time. If contact-beds are used as storm filters, to pass at the rate of 500 [600 U. S.] gallons per superficial yard in 24 hours to comply with the regulations of the Local Government Board, they would require to be 8.89 ft. deep, and the rate of filtration to pass this quantity through a storm filter would be 4.44 ins. per hour. The time of contact in a contact-bed, calculated as before, would be 8.889 ins. per hour. A 5-ft. filter would, at the lower rate of 4.44 ins. per hour, pass 500 [600 U. S.] gallons per superficial yard, while a bed 8.889 ft. in depth would be required to deal with 500 [600 U. S.] gallons per superficial yard as a contact-bed, and would have a quicker rate of contact. As good, if not better, purification could be procured by once passing through a filter as by twice passing through a contact-bed, with the advantage that the same area of filters would purify double the quantity of sewage that could be passed through the contact-beds; and, moreover, less fall is required in the case of a filter than in the case of double contact-beds, so that filters can be used in places unsuited for contact-beds.

The urban district council of Friern Barnet, since 1 completed the work established [begun?—Ed.] in 1885 for the purification of the sewage, have added to the works a series of contact-beds, and there is therefore on these works the means of comparing the result of these contact-beds with the results secured before their introduction. The abundant formation of nitrates in the filtered effluent from the controlled filters, compared with the smaller amount produced in the effluent from the contact-beds, shows at once the superiority of the controlled filter over a contact-bed. The formation of nitrates in a sewage effluent is of the greatest consideration, as such an effluent when turned into a polluted stream tends to purify it, as the nitrates undergo reduction and oxidize the impurities present in the stream.

A good effluent ought not to contain more than .10 grain of albuminoid ammonia per [Imp.] gallon or absorb more than 1.0 grain per [Imp.] gallon of oxygen. The controlled filters always comply with this standard, but it is very different in the case of the contact-beds.

Table II. gives the results of recent analyses of the sewage of Friern Barnet.

A PLEA FOR THE CONSERVATION OF NIAGARA FALLS.

Under the heading, "The Impending Destruction of Niagara Falls," a leaflet is being distributed by the American Civic Association, whose headquarters are in the North American Building, Philadelphia. As a statement of the feelings and arguments of those who fear that this great natural attraction of our country is in imminent danger the contents of the leaflet will doubtless interest many of our readers and we therefore reprint practically the whole of it, as follows:

Ten power-developing companies (four American and six Canadian) now have authority to utilize 35¼% (1,339,500 HP.) of the effective power of the Falls. These developments, if fully utilized, will, in the judgment of engineers, destroy the American Fall, for the reason that but 12% of the average flow of Niagara passes over the 1,000 ft. of the American Fall.

If even half the authorized amount of water is withdrawn above the cataract, the American rapids will be entirely bare of water except for a thin trickle to pass over the face of the American Fall.

Five companies are now exercising their franchises and actually developing power, while the others are actively preparing to do the same.

The power development so far has not resulted in any general benefit to the people at large. The city of Buffalo is lighted by Niagara-made power, for which it pays $75 per 2,000 c. p. arc light per year, a sum considerably above the average price paid by American cities for the same light produced by means of burning coal. Trolley fare in Buffalo, the trolleys being driven by Niagara power, is five cents, and the trolley companies pay no more taxes and no greater proportion of gross revenue to the city of Buffalo than the average of American cities where coal-produced electricity is utilized.

If half the authorized power is developed by the companies now having permission, and if half this power is sold at half the price now being charged, an income of approximately twenty millions of dollars will be received by the ten companies involved, of which not one cent would go to the State of New York, while the Dominion of Canada would receive approximately only $240,000 per year. As it is estimated that there are less than one thousand stockholders in the ten companies involved, the benefits conferred are obviously confined to a very few persons.

The preservation of Niagara Falls can be accomplished only by the combined action of the American and Canadian governments.

According to Charles M. Dow, President of the Board of Commissioners of the New York State Reservation at Niagara, the Treaty of Ghent, which fixed the boundary lines in the Niagara River, "devolves upon the two governments the moral duty of protecting it." The State of New York has invested in the Reservation at Niagara Falls about $2,500,000. Quoting Mr. Dow, "Whatever impairs the value of Niagara Falls as a spectacle impairs the value of that investment."

The Ordinance of 1787 recognizes the common interest of all the states and territories in the Niagara River, for it recites that all waters flowing into the Mississippi and the St. Lawrence rivers and the carrying places between shall be held as public highways forever free to the people without impost of duty.

TABLE II.—ANALYSES OF FRIERN BARNET SEWAGE AND EFFLUENTS; SAMPLES OF MARCH 27, 1905.
(Grains per [Imp.] Gallon.)

	1 Crude Sewage.	2 Effluent from sewage tanks.	3 First 3 minutes' discharge from contact-beds.	4 Average of 1¼ hours discharge beyond first 5 minutes.	5 Effluent from contact-beds while not discharging.	6 Final Effluent from filter.
Total dissolved solids	69.3	58.1	62.3	61.6	60.2	71.4
Chlorine	7.45	6.71	7.45	7.45	7.45	7.45
Equal to sodium chloride	12.28	11.06	12.28	12.28	12.28	12.28
Nitrogen as free ammonia	4.032	3.360	2.38	1.540	2.02	.4337
Albuminoid ammonia	.896	1.400	.531	.644	.392	.1260
Nitrates	nil	trace	trace	.924	1.344	3.262
Nitrites	nil	nil	nil	.129	nil	nil
Oxygen absorbed in three minutes at 80° F.	.672	.602	.280	.210	.266	.070
Four hours at 80° F.	2.436	2.072	1.057	1.001	.924	.343
After five days' incubation at 80° F. in 3 min.	.....	.....	.133	.224	.182	.091
Total suspended matter	23.1	6.3	.....	.....	.....	.....
Organic	18.2	6.3	.....	.....	.....	.....
Inorganic	4.9	.....	.....	.....	.....	.....

3 and 4.—Brownish and slightly turbid; slight smell both before and after incubation.
5.—Slightly turbid; no smell either before or after incubation.
6.—Clear bright effluent; no smell either before or after incubation.

THE ARTISAN SCHOOL OF SYRACUSE.

The new project of establishing a School of Trades in Syracuse, referred to in the "Society Proceedings" of our issue of Nov. 23, is arousing great interest among leading manufacturers, not only in the immediate locality, but in other sections of the country. Prof. John E. Sweet, of the Straight Line Engine Works, who is the leader in this enterprise, is receiving letters from employers in various cities, emphasizing the need of such a school, and congratulating him on the start already made.

Although the idea of a School of Trades is new in this country, such schools have been established in Germany for some time, with very practical results in the way of increase in the number and competency of skilled workmen. This system is an outgrowth of the old apprenticeship system, which seems to have lost its practicability in the present Industrial Age.

Although the plans of the Syracuse promoters of the enterprise are not fully completed, it has been determined to make a small beginning, as soon as a site has been selected, and a majority of the capital stock subscribed.

The only educational requirements for admission, will be a very elementary knowledge of reading and writing, and enough arithmetic to enable the boy to solve ordinary problems of the machine shop, such as lathe compounding for screw-cutting, etc. A small entrance fee will be charged as a guarantee of good faith, which will be returned to the student when he has completed the stipulated course. Negotiations are on foot for securing the services of a thoroughly practical man, whose entire time will be devoted to the work of the school. Prof. Sweet has shown his great interest, by offering to devote half his time to its supervision.

The plan, at present, is to start with a machine shop, having a small but modern equipment, and if this is successful, other shop courses will be organized. In connection with the machine shop, drafting and pattern-making will be taught. About two hours per day will be devoted to making drawings of objects, and not copies of book drawings, as is generally customary in elementary schools of drafting. Later, a foundry will be added. The work will not be carried on in classes, but by individual instruction. Students will not be paid for their work, but will be promoted to more difficult work as rapidly as they become proficient.

As soon as the school becomes able to do satisfactory work, jobbing will be undertaken, and it is hoped that enough money will be earned to make the school self-supporting. The stockholders will receive no return from their investment save the opportunity to secure more competent workmen for their shops. Any profits made will be devoted to an endowment fund. Successful results will probably cause the establishment of similar schools in other cities.

A STEAM RESERVE FOR AN ELECTRIC TRANSmission system will be installed by the Missouri River Power Transmission Co., which operates a 50,000-volt water-power transmission line in Montana. A large part of the output of the system is transmitted to the city of Butte, Montana, and the Anaconda mining district, where continuity of service is very important, and the service has grown to such an extent as to warrant the erection of a reserve plant as a protection against serious fluctuations in available water power. The steam station will be equipped with Westinghouse steam turbines of 2,000 KW. capacity each, two units for the present. They will operate under 150 lbs. steam pressure with 100° superheat and 28 ins. vacuum, and will run at a speed of 1,200 r. p. m. Completely enclosed generators of revolving field type, with forced ventilation, will be direct-coupled to the steam turbines. The units are to be capable of giving full load non-condensing and 50% overload continuously when run condensing. The output will be 60-cycle three-phase current at 2,400 volts. The enclosed construction of the alternators is expected to eliminate the peculiar hum of open high-speed generators.

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It has been clearly evident for some time that the next important application of electricity in railway operation is pretty certain to be for the propulsion of trains in long tunnels. For the underground tunnel railways in cities, electric traction is already in use in New York, Boston, London, Paris, and Buda Pest, and is soon to be adopted in Berlin and Philadelphia.

For long tunnels beneath mountains or rivers, however, the only case that we now recall where electricity has already displaced steam is the railway under the Mersey River at Liverpool, and this is a city passenger railway and not a general traffic road, so that the change was comparatively easy. A change to electricity is much more difficult where a tunnel is located on the main line of a general traffic railway, so that a change of engines is required if electricity is adopted for operating the tunnel. As our readers are aware, the tunnels of the Pennsylvania and New York Central railways entering New York City are to be operated by electric traction when completed; and it is now announced that the great Simplon tunnel, the longest railway tunnel in the world, is to be operated by electricity when it is opened for traffic. The opening is expected to take place early in the coming spring.

These facts are certain to lead railway managers to canvass the matter of operating other long, main line tunnels by electricity and avoiding the present dangers to trainmen and passengers of death by asphyxiation. The first change of this sort, we understand, is likely to be made at the St. Clair tunnel, on the Grand Trunk Ry. As our readers will remember, this single-track tunnel beneath the St. Clair River is nearly a mile in length, and its approaches, being below the level of the adjacent country, make natural ventilation much less effective than is the case with tunnels under mountains. Special steam locomotives have long been used to haul trains through the St. Clair tunnel, and a change to electric motive power therefore will mean only that electric locomotives will replace these steam machines.

Two other famous tunnels where electric operation ought to be adopted, and very probably will be before long years, are the Hoosac tunnel and the Cascade tunnel of the Great Northern Ry. in Washington. Abroad, the long Alpine tunnels in Switzerland are pretty sure to be operated by electricity eventually, although the change may be deferred until all the Swiss roads are altered to electric operation, using energy generated by water power, which is a change that is now regarded as certain to be made in the near future.

Sewage treatment as an art is mostly confined to the last 50 or 60 years; as a science, if such it may yet be called, to the last 15 or 20 years. Probably the only living engineer who has witnessed, and to a large degree shared in, practically the whole development of sewage treatment is Mr. Baldwin Latham, M. Inst. C. E., of London. On this account, and because the name of no British sanitary engineer is more familiar to American readers of this journal, we think particular interest will center in the abstract of Mr. Latham's recent presidential address before the Association of Sewage Works Managers, which is printed elsewhere in this issue.

Mr. Latham's chronicle of chemical processes and patents, incomplete as it of necessity was in the limits of an address, emphasizes anew the dreary waste of blasted hopes and useless sewage works which have characterized a half century of sewage treatment in England. The author's brief review of land treatment is chiefly confined to his own experience at the Croydon sewage farms and to the experience there and elsewhere from which it was learned that where sewage is treated on clay land, as is so after the case in England, no underdrains should be used.

Perhaps the most interesting portion of the address is the one dealing with intermittent filtration and with Mr. Latham's "controlled filters" at Friern Barnet and elsewhere. In this, and also in the following section of his address, in which contact beds and filters are compared, Mr. Latham shows his decided preference for filtration rather than contact. He says nothing on percolating or sprinkling filters, which we should like to have had him compare with his controlled filters. The latter are described by him as composed of

> a certain amount of surface soil mixed with other ingredients, such as burnt ballast (clay) and breeze; and over the top of the filter is placed a thin layer of sandy surface soil so as to control the rate of filtration.

The address gives little idea of the size and arrangement of the filtering material. Fortunately we can present some information on this subject, based on notes taken in Mr. Latham's office in 1904 by a member of our editorial staff, through the courtesy of Mr. George Latham. Mr. Baldwin Latham's specifications for some controlled filters built three years or so ago for Pontefract, England, called for a total depth of about 4½ ft., as follows:

(a) A bottom layer of 12 to 18 ins. of burnt ballast or cinders, broken to pass a 1-in. and be held on a ¼-in. screen.

(b) 36 ins. of mixed material, including equal parts of (1) fine burnt ballast or clinker to pass a ¼-in. mesh; (2) clean and fresh breeze from gas works; (3) sandy surface soil, free from clay or loam. These materials (1, 2 and 3) to be thoroughly mixed before being placed in the bed.

(c) A top layer of 6 ins. of sandy soil, free from loam, clay or stones. The sewage was to be distributed over these beds by means of half round pipes, let into the surface of the bed; the main carriers to be 15 ins. in diameter and 33-ft. c. to c., and the 6-in. branch carriers to be 10-ft. c. to c., laid herring-bone fashion. The underdrains were to be laid 30-ft. c. to c., and to have their bottoms perforated, and their outer ends provided with ventilation pipes. This same general plan was followed, we understand, at both Pontefract and Carshalton. The Pontefract beds receive either a settled or a lime-treated sewage, at a rate, as designed, of 185 (U. S.) gallons per sq. yd. per day, or about 900,000 U. S. gallons an acre. They have a total area of 6,414 sq. yds., or about 1 1-3 acres. There are also 3,486 sq. yds. of storm water beds, similar in character to the other beds, but with the middle layer only some 18 ins. thick. The population of Pontefract is about 15,000.

The method of operating the controlled filters is not stated by Mr. Latham, but we understand that they are operated substantially as intermittent filters. In fact, they seem to be merely a special type of intermittent filters, operated at a high rate.

It would be interesting to test the relative sanitary efficiency of one of these controlled filters and an intermittent sand filter, and also to compare the capital and operating charges of each per 1,000,000 gallons of sewage treated to the same degree of purity. In England, the controlled filters might do the same work, quantitatively and qualitatively, at less capital and operating expense than would ordinary intermittent sand filters, but in America, or those parts where sandy land near cities is abundant and cheap, the outcome would be more doubtful.

It is remarkable that agriculture, which is the oldest of the industrial arts, should be so slow in taking advantage of the progress of science, and particularly of the science of engineering. This backwardness on the part of the farmer is largely due to his economic independence and his isolated life. But both his independence of and isolation from others has grown rapidly less with the development of manufactures and commerce, the railway and telegraph, and, of late, good roads and the telephone. In recent years our state and national governments have provided agricultural colleges and experiment stations and no end of literature for the farmer. All these industrial changes and educational facilities are interacting and uniting to open up a more or less new and distinctive field for engineers which may perhaps best be called agricultural engineering. Thus far the agricultural schools have taught but little that could be dignified with the title engineering, either not recognizing the need of such teaching or feeling that it should be sought and found in the schools of civil and mechanical engineering. A moment's reflection will show that the agricultural engineer needs both civil and mechanical engineering, and not a little besides that is not to be found in either, as taught. Such a combination, as a rule, can probably best be given by the agricultural schools, since the instruction in engineering for the most part will be supplementary to that in agriculture and can be best planned and given in that connection. Naturally, the so-called land grant colleges would be the first to offer instruction in this new line of engineering. Some of the reasons for entering upon such work, together with an account of what has been done in this direction, are given elsewhere in this issue, by Mr. C. J. Zintheo, formerly Professor of Agricultural Engineering, Iowa State College, and now connected with the U. S. Department of Agriculture. The article bids fair to interest many of our readers, inasmuch as it suggests many possibilities for engineers in the future. Not the least of these, we believe, will be in the line of developing greater efficiency in agricultural machinery of various sorts, and of practical instruction in using such machinery to the best advantage. Other important lines will be the adaptation of concrete and other building materials to the need of the farm; road building; drainage; and household and dairy sanitation.

While the railway motor car is making very rapid progress in Europe, its development in this country is very much slower, although there are numerous points where this class of equipment would be peculiarly applicable and advantageous. As we have pointed out in former articles on this matter, these cars are adaptable to two different classes of service: First, for branch lines, as a substitute for the ordinary locomotives and trains on such lines; Second, for local service between certain points on main lines supplementing the regular trains and providing for intermediate stops not made by the latter. In England, steam cars are by far the most generally favored, though oil-engine cars have also been tried. In various other European countries, steam and gasoline or oil engines are used, the latter sometimes in connection with electric generators and motors. Steam cars are apparently not regarded with much favor in this country, but several designs of gasoline and gasoline-electric motor cars have been devised, some of

which have been built and tried experimentally. We believe, however, that not more than two or three are in use. In another column we describe some gasoline cars built by the Union Pacific Ry., and it is worth noting that these have been designed by the railway company's superintendent of motive power, and built at the company's shops. In a former article we pointed out that in Europe many, if not most, of the motor cars are designed by the officers of the mechanical departments of the railways, rather than by manufacturers, and that many of them are built at the railway shops. Under these conditions the designer is apt to be very much more familiar with the requirements to be met with (both from a mechanical and a traffic point of view), and the service is likely to be given better attention than when the officials have merely a casual interest in the machine. In this country, most of the cars so far tried have been the work of manufacturers, and one problem has been to interest railway officials even to the extent of allowing the cars to be tried on their roads. Within the past few months we have had numerous reports that certain railways were to introduce motor cars, but in nearly every case investigation has shown that the railways have taken little active interest in the matter, but have simply agreed to try certain cars when the inventor or designer is ready to supply them. It is for this reason that the work of the Union Pacific Ry. is of more than ordinary interest. In the numerous press accounts of the Union Pacific Ry. cars great stress is usually laid upon the high speeds attained, and we are officially informed that a speed of over 60 miles an hour has actually been reached. This matter is naturally exploited by the press, owing to its spectacular interest, but as a matter of fact high speed is rarely an important requirement in the class of service for which motor cars are adapted. Light weight, easy riding, easy handling and reliability for regular service week after week, with a minimum of attention for repair work, are requirements of much greater importance than capacity for very high speed.

LENGTHENING ROTARY CEMENT KILNS AS A MEANS OF INCREASING THEIR FUEL EFFICIENCY.

Announcement is made in another part of this issue of an installation of six 136-ft. rotary kilns to be made for a western Portland cement works. The first rotary kilns used in America for cement burning were 30 ft. long. This length was increased to 40 ft. and then to 50 ft., and finally to 60 ft. for kilns burning dry materials and to 80 to 90 ft. for kilns burning wet materials, and at these lengths the advance stopped for a number of years. The great majority of American cement plants are to-day equipped with 60-ft. kilns 6 and 7 ft. in diameter. In 1904 Mr. Thomas A. Edison installed and put in operation at the Edison cement works two kilns 150 ft. long and 9 ft. in diameter. The result of the experiment was successful and cement works engineers following Mr. Edison's lead began to increase the size of their kilns. None of them felt quite inclined to make the jump from 60 ft. to 150 ft. that Mr. Edison had made, but kilns 100 ft. long, 125 ft. long, and, now, 136 ft. long, began to be designed and installed with increasing frequency. It is natural to inquire why this change of practice should come about.

The rotary cement kiln is not an economical thermal device. It is very wasteful of fuel. Its economy and efficiency as a means for calcining cement mixtures to clinker comes from other things. To illustrate, it requires about 40 lbs. of coal to burn one barrel of cement with a vertical kiln while it requires from 100 to 200 lbs. of coal to burn one barrel of cement in a rotary kiln. But in the case of the vertical kiln the raw material, after being reduced to powder, has to be molded into blocks or bricks, which have to be charged by hand into the kiln, and finally, when the burning is completed, the blocks have to be sorted by hand to remove those imperfectly burned and then crushed before the clinker can be admitted to the grinding machines. The rotary kiln does away with all of these manipulations. It takes the powdered raw material, either dry or wet, by mechanical feed and burns it to clinkers varying from the size of a pea to the size of a walnut which can be fed directly to the grinding machines; there is no molding of blocks involving preliminary drying with wet mixtures and preliminary wetting with dry mixtures, no sorting out and discarding of underburned material, and no preliminary crushing of the clinker. It is in the labor saved before, during and after burning and not in its efficiency as a furnace, that the economy of the rotary cement kiln exists.

So long as Portland cement would fetch $2 and $3 a barrel, manufacturers were not disposed to scrutinize too closely the fuel performance of their kilns; capacity was of more importance than minor economies in cost of calcination. With cement at not much over a dollar a barrel the matter assumed another aspect. Fuel waste became a loss to be looked into and remedied. It must be understood that we are speaking now of American conditions. In Europe fuel waste in the rotary kiln had received attention long before, in fact as soon as American rotary kiln practice began to be taken up in European cement works. There the greater cost of fuel and the smaller cost of labor put the problem of kiln efficiency upon a radically different basis than it stood in America.

Returning to American cement works, it was seen in a brief review of the problem that two ways were open for reducing the loss due to fuel waste in the kiln. One way was to so design the kiln and its appurtenances as to utilize more completely the full heat value of the fuel within the kiln itself, that is in burning cement clinker. The other way was to leave the kilns as they were but to trap the waste hot gases and use them under steam boilers for generating power. The two methods are radically different in principle as will be seen at a glance. Both have been tried and which one is the better is still a subject of discussion. We shall refer again to the possible merits of waste gas boilers, but our first object is to review the question of improving the kiln proper.

Several devices have been suggested for improving the thermal efficiency of the rotary cement kiln. It has been proposed to use two jets of coal dust; to water-jacket the hottest zone as is done in blast furnaces; to jacket the kiln to reduce loss of heat by radiation; to introduce interior ribs to retard the movement of the material, and to do various other things. None of these remedies have gotten beyond an individual installation and many of them exist only as propositions on paper. In fact, the only method suggested for improving kiln efficiency that has been taken up in actual practice is that of lengthening the kiln cylinder. This method, as we have noted above, is gaining continually increasing favor.

Exactly what is gained in economy by longer kilns and in what way does this gain come about? In a general way it is evident enough that by making the kiln longer the gases of combustion are compelled to leave the kiln at a lower temperature and hence a part of the heat now wasted in the shorter kilns is rendered useful, but to how much does the gain thus made amount? There have been many speculations on this point, but very few actual test determinations have been made. Even factory figures of fuel consumption that bear the stamp of reliability are hard to get. Manufacturers doubtless possess such figures but they have not made them public and are not likely to, so long as they think that competitors can get any good from them.

Taking the few and incomplete data at hand, however, we find a notable economy in fuel resulting from the use of long kilns. When Mr. Edison's kilns 150 ft. long and 9 ft. in diameter were first installed the managers of the works stated that the monthly average of each kiln was 30 bbls. of cement per hour with a coal consumption of 80 lbs. per barrel. The output of 60-ft. kilns working on practically the same material is from 7 to 10 bbls. per hour with a coal consumption of 80 to 140 lbs. per barrel. Referring to the Edison kiln, Mr. A. V. Bleininger says:* "Its fuel consumption probably approaches quite closely [illegible] lbs. per barrel." In a recent discussion of rotary kiln efficiency the German authority, Mr. Michaelis, Jr., states that rotary kilns 90 ft. long are in use in Germany that, burning dry materials, turn out 300 bbls. per day with a fuel consumption of from 60 to 75 lbs. of coal per barrel. This economy is not due alone to increased kiln length, however, but is brought about in part by supplementary devices for regulating the admission of raw materials, fuel and air to the kiln. Taking these figures as they stand they show a close approximation to the vertical kiln in fuel economy.

Figures of actual cement output and actual fuel consumption collected by Mr. E. C. Eckel and published in his excellent treatise, "Cements, Limes and Plasters," show that 60-ft. kilns working on cement rock and limestone may be expected to produce from 180 to 250 bbls. of cement per day per kiln with a fuel consumption of from 85 to 160 lbs. of powdered coal per barrel, while 80-ft. kilns working on the same material may be expected to produce from 225 to 300 bbls. per day per kiln with a fuel consumption of from 85 to 120 lbs. of coal per barrel. The same authority states that the 150-ft. kilns of the Edison works turn out 375 bbls. of cement per kiln per day with a fuel consumption of 65 lbs. of coal per barrel, and this with practically the same material as gives the figures quoted previously for 60 and 80-ft. kilns. This material, the cement rock and limestone mixture of the Lehigh cement district, is noted, however, for its remarkably easy clinkering. A 60-ft. kiln working on limestone and clay will, on the average, record neither so great an output nor so small a fuel consumption.

We have stated that test investigations of the economy of long kilns are rare. It is worth particular note, therefore, that in another column of this issue we publish an account of such tests made on a long kiln installation. For the main argument drawn from these tests the reader is referred to the paper itself. Some of the figures are, however, worth separate study here. The plant tested uses a wet mixture containing 52 per cent. water and burns it with a local coal having a heat value of 10,094 B. T. U. With its 100-ft. kiln it gets an output of 166 bbls. of cement per kiln per day with a fuel consumption of 180 lbs. of coal per barrel. These are very satisfactory results as a brief examination will demonstrate.

Mr. Soper, the author of the paper, figures from his test records that there is a saving of 48 lbs. of coal per barrel of cement as compared with a 60-ft. kiln working under the same conditions. Mr. E. C. Eckel, in his treatise quoted above, gives a record of a 110-ft. kiln burning a wet mixture that produces 135 bbls. of cement per day with a fuel consumption of 150 lbs. of coal per barrel. Using the same materials he gives the following figures as the results that may be expected from kilns of the lengths more commonly used: For 60-ft. kilns an output of 60 to 140 bbls. with a fuel consumption of 150 to 250 lbs. per barrel; for 80-90-ft. kilns an output of 80 to 150 bbls. with a fuel consumption of 140 to 220 lbs. per barrel.

Though these records of long kiln efficiency are of rather haphazard character, it will be observed that they all agree in showing a decided gain both in output and in fuel economy resulting from the increase in length. This gain is obtained whether the kiln is working on a dry mixture or a slurry, though naturally it may be expected to be smaller with the wet mixtures. In view of these facts we need not go further in search of the answer to our first question as to why cement mill engineers should, after having apparently settled down to the use of 60-ft. kilns, suddenly begin to build kilns of nearly twice that length for it is quite certain that in the future very few new cement plants will be fitted with kilns less than 100 ft. long.

It may not be supposed, however, that the solution of the problem of rotary kiln fuel economy afforded by lengthening the cylinder lacks objections. The cost of the kiln plant is in the first place greatly increased; this is true even in new plants where everything is planned on the basis of long kilns. In many existing plants lengthening the kiln necessitates the reconstruction of a

*"Manufacture of Hydraulic Cements," Bulletin No. 3, Ohio Geological Survey, Columbus, O.

large part of the remaining plant and buildings to give room for the larger kiln units. It may readily occur, therefore, that some method of utilizing or regenerating the heat wasted from the kiln will be a far more economical means of reducing the losses now suffered than will the introduction of long kilns. Practically speaking, only two methods of utilizing waste kiln heat in cement mills have been seriously taken up in America. One method is to trap the hot gases coming from the kiln and passing them under boilers for generating steam; the other method is to utilize the heat from the cooling clinkers to preheat the air used in combustion in the kiln. It is not proposed to enter here into an examination of the question of waste kiln gas utilization but the reader who cares to pursue the subject may consult the papers by Mr. A. B. Helbig in Engineering News, Feb. 16, 1905, and by Prof. R. C. Carpenter in the "Sibley Journal of Engineering" for March, 1904.

LETTERS TO THE EDITOR.

A Water Wheel Cut from a Solid Block of Pine.

Sir: I recently saw a water wheel taken from an old mill which seems worth mentioning, if for nothing more than to be placed in the list of engineering curiosities:

The wheel, consisting only of the runners, and without guides, was cut from a solid block of pine. It was 4 ft. in diameter, about 12 ins. deep, the periphery left solid and continuous and bound with a metal hoop. The curved parts of the runners were cut thin and symmetrically curved, conforming closely one with another. It had been set with vertical shaft, and after running 18 years was in good condition, except for certain broken flanges which had suffered violence. The wheel had worked under a head varying from 4 to 12 ft. The wood seemed sound and was slightly water-worn. This work of art was carved by the miller between whiles, and for 18 years has been doing 14 HP. of work, so it was stated, grinding grist near Wilson, N. C.

Yours truly, John W. Hays.

Petersburg, Va., Dec. 9, 1905.

Is Caked Cement as Good as Fresh Cement?

Sir: At a South Atlantic city where considerable quantities of Portland cement of various good brands is stored the dealers are regularly in the habit of pounding up with heavy wooden mauls cement which has become lumpy, repacking the same, and selling it for first class cement. The agent for one of these dealers contends that cement which has been "reconditioned" in this way is not only as good, but better, than that which has never been allowed to get lumpy and been repulverized. Is there any basis for this statement, or is it not a fact that such cement is unfit for use in any first class masonry? Subscriber.

Savannah, Ga., Dec. 12, 1905.

(We know of no direct test of the strength of mortar or concrete made with caked cement, but in our issue of Jan. 5, 1903, there was published some exhaustive experiments on the effect of retempering on the strength of mortars. In these experiments mortar was mixed and allowed to take an initial set, then broken up and mixed over again, and this was repeated for eight hours, after which test briquettes were made up. Various brands of Portland and natural cement were tried both neat and with sand. The tests showed that this retempering decreased the strength of sand mortar briquettes made with Portland cement at the end of the month about 25% on the average. It will be recognized that the cement was probably injured much more in these tests than it is ever likely to be by mere exposure to moist air in a warehouse.

We should say that the injury to cement by caking in storage depends on how hard the caking is. If it can be crushed by hand with wooden mauls, so that it will become of its original flour-like consistency and the user of the repacked cement cannot tell it from fresh cement, then we do not believe it has suffered any material injury and is rather the better for storage. On the other hand the bulk of the cement in the bag may crush up to flour and yet parts of the caked portion may be left as very small hard lumps after crushing by hand. In this case the cement is injured, for these small lumps are valueless as cement since they will not serve to fill the voids between and coat over the particles of sand.

A practical test would be to put a sample of the cement through a sieve and see if it contains any considerable proportion of these small caked lumps. If it does contain say 5% or 10% of such lumps, then the purchaser receives only 95% or 90% of the total contents of a bag or barrel in useful material.

We shall be glad to hear from any of our readers who can furnish tests of caked cement.—Ed.)

Burning or Overheating Rivets.

Sir: In answer to the questions asked by your correspondent "Subscriber," published in your last issue (p. 632), permit me to offer the following:

(1) Actual experiments have shown that repeated heating to a straw color injures the metal in steel and iron rivets. Such heating, however, produces another important defect: it coats the metal with a thick layer of magnetic oxide, in addition to pitting the rivet. When, therefore, a rivet is entered into a hole the coating of oxide absolutely prevents making a tight rivet. The pits also hold oxide. Tapping the rivet to remove the oxide, which is commonly resorted to, does not remove it.

(2) Yes! Many inspectors in New York city permit burnt (sparking) rivets to be driven, as I have seen myself, as many are of the opinion that sparking or burning occurs only at the extreme end which is formed into the head, and therefore claim this is not injurious. I maintain that every burnt rivet is materially injured and should be rejected.

(3) As above stated all pitted rivets should be rejected for the reasons given; also because the dust formed in the holes will admit moisture and be the cause of corrosion of the rivet and sheets, because the oxide is powdered by the severe blows required to upset the rivet. It requires no special expert to decide this question.

(4) The difference between what is "practiced" and what is preached is largely due to the desire of most engineers

(a) to have the work rushed;
(b) to have the name of an easy boss;
(c) to avoid being called "too d..... particular;"
(d) to avoid all sorts of adverse reports about him to his superior, and criticism;
(e) to avoid losing a job for lack of using what has been called "common sense."

"Many reputable engineers are willing to allow in actual practice methods of heating rivets that they are not willing to acknowledge in print," because the work thus becomes easier. Gus. C. Henning.

150 Nassau St., New York, N. Y., Dec. 15, 1905.

Sir: In your issue of Nov. 9 "Subscriber" asks, "should a rivet that is slightly pitted be condemned?" In the next issue Mr. Gus C. Henning answers this categorically in the affirmative, adding that the pitting is evidence of overheating and injury to the metal.

I believe Mr. Henning would not have made this positive statement if he had made the following simple experiment: Take a rivet of the best quality and heat it just right for driving, and drive it with the axis vertical Before driving throw some steel scale into the lower cup, and an imitation burnt head will be formed that will probably cause nine out of every ten engineers or inspectors to say that it is burnt and should be cut out. The pitting produced by this means looks exactly like that found on a piece of metal that has been overheated and allowed to burn. It is well known that scale forms on steel when at a working heat and in no wise mistreated. If the rivets are not cleared of loose scale by a knock before driving and if the lower cup, in case of vertical driving, is not kept clear of scale, the heads are almost sure to be pitted.

It is doubtful if the pitting of rivets is evidence of burning. A piece of steel placed in a furnace and allowed to become too hot, so that when it is removed it "spits fire," and then allowed to cool without being hammered, will be pitted on account of the burning and melting of the metal in spots. If this same piece of metal while hot had been cleared of scale and forced into a smooth die, it would probably have a smooth, shiny surface with no sign of pitting to show that it had been burnt.

There is no doubt that a burnt rivet is bad, but the best time to tell if the metal is burnt is when the rivet is taken from the forge. If sparks are flying from it and melted metal falling from it, it should be thrown away. I have seen rivets with no heads and a clean fracture in the shank. Evidently the heads had popped off in the shrinking of the metal. This was probably due to the forging of the metal when it was too hot, the result being a metal of crystalline structure and very brittle.

It is not infrequent that rivets with cocked or pitted heads, that have been heavily driven by power, are cut out and replaced with neater rivets that do not fill the holes nearly so well as the others.

The most common fault in rivet driving, especially in the field, is heating the rivets so that the heads are dark red while the points are spitting hot. This cannot be too strongly condemned.

Yours very truly,
Edward Godfrey.

Monongahela Bank Bldg., Pittsburg, Pa., Dec. 16, 1905.

(It may be worth while to quote here the provisions of the specification for the Manhattan Bridge over the East River, New York City, covering rivet-heating. This specification is one of the most recent for large bridge work; it emanates from an office—the Department of Bridges of the City of New York—which includes many able engineers and has had much large bridge work under its charge; and its riveting clauses cover both nickel steel and ordinary carbon steel rivets. The clauses for rivet-heating are:

Rivets, both in the shop and in the field, shall be heated in oil, gas or hard coal furnaces of a form approved by the Engineer. Hand forges can be used only in special cases by permission of the Engineer.

Rivets must be heated uniformly throughout, or with the heads hotter than the points. Under no circumstances shall rivets be driven with points hotter than the heads.

Any riveting gang refusing to observe this rule strictly shall be dismissed.

Rivets must not be burned. Rivets that "spit" on being taken from the furnace shall be thrown away.

These clauses require substantially the same features demanded by our correspondents. But we quote them as an isolated example; in general, rivet heating is not covered by detail clauses in structural specifications, although we may look forward to the time when such requirements will be common practice.—Ed.)

Direct-Current Electric Traction at Higher Voltage.

Sir: The hope of extended electric equipment and operation on the main lines of trunk railways (as distinguished from special sections such as terminals, tunnels and congested sections) lies not alone in the possibility of increased traffic or economy of operation, but in such limitation of capital investment as will keep the burden of interest account measurably below the savings effected.

A vital element in this investment is of course the cost of substations and conductors. As to the latter, it is evident that greatly increased potentials are necessary either to keep down their size, or with any given cost of conductor per mile to increase the distance between substations, with resultant less aggregate investment in them and higher economy in operation. These are common requirements no matter whether alternating or direct currents are used. The bearing of the increase of potential upon the problem is quite evident from a consideration of the following general facts: 1. When the traffic increases directly as the mileage, the distance between substations, with any given line-loss and size of working conductor, will increase directly as the working potential increases. 2. On the other hand, so long as the train load between substations is not increased, this distance will increase as the square of the potential. 3. Taking the average of service conditions on a trunk line, the allowable increase in substation distance will lie between these extremes. To illustrate: Doubling the working potential would probably on an average allow trebling the substation distance, and trebling the potential would very likely allow an increase to, say, five times in distance.

To meet the various economic requirements, and proceeding on the assumption that 500 to 600 volts is the limiting standard for direct current operation, the principal energies of many engineers and manufacturing companies have of late been devoted to operation by alternating currents, with varying degrees of success as applied to railroads, with the abandonment of third rail construction and adoption of a special type of overhead contact. These developments have resulted in a variety of designs for both polyphase and single-phase motors, and considerable divergence in views as to potentials, frequency, and mode of construction and operation where the single-phase has been adopted.

It is not my purpose at present to enter into a discussion as to the comparative merits of the various systems, all of which have their field of usefulness. I have long advocated, and am keenly alive to the economic bearing of increased potentials, however obtained, but also mindful of certain practical features which must be considered in connection with them. I believe, however, that where alternating-current motor operation, with overhead construction, is adopted, there is little reason for halting at any moderate limit, but that such potential should be used as may be necessary, all things considered, to get a reasonably full measure of the possible economy of investment.

On the other hand, I have frequently pointed out that the limits of direct current operation are by no means reached, and five or six hundred volts was an arbitrary

standard which present possibilities in construction of apparatus no longer warranted maintaining when leaving the field of tramways to take up the consideration of trunk line applications.

The time has now come, I think, in view of the developments which are taking place on the terminals of the roads entering New York City, the interest which railway officials are taking in the subject, and especially because of the various claims which are from time to time made, when equipment engineers, in considering the practical application of electricity to the more serious problems of railway operation, shall have as a choice the possibilities of higher limits in direct current as well as in alternating current operation. To that end I beg therefore, to announce that if in any case, after considering the various kinds of equipment possible, it should seem from an analysis of all elements entering into the problem that a comparatively high-potential direct current equipment would produce the best net results, I am prepared to engineer and carry to a successful conclusion a direct current installation at a working pressure, even on a third rail, of not less than 1,500 volts, which is at least two and a half times that ordinarily used.

I believe it may be admitted that, although oftentimes having taken a somewhat radical and advanced position in electric railway matters, I have never made a public proposal which I have not been ready when called upon to carry out, and should conditions arise warranting an equipment such as is proposed, I propose to establish a new and necessary comparative standard in equipment possibilities. And I venture further to affirm that 1,500 volts is not the limit of practical direct current operation.

Frank J. Sprague.

20 Broad St., New York, N. Y., Dec. 14, 1905.

Notes and Queries.

F. G. H., Jr., Brooklyn, N. Y., writes:

Will the range (actual and theoretical) of a .30 caliber bullet, fired from a gun weighing 10 lbs. and suspended by wire so as to be free to recoil without friction, be the same as that of a bullet of the same caliber fired from a gun having an equal bore and similarly suspended, but having a weight of 10,000 lbs? This problem has puzzled the writer and a number of his friends who are readers of your valuable paper. If you can throw any light on the subject and give an explanation of how you arrived at the correct solution it would be greatly appreciated.

The bullet fired from the heavier gun will have greater energy and greater velocity, hence, greater range, as may be readily shown. It is to be premised that the same charge of powder will expend the same amount of effective energy—that is, the sum of the kinetic energies of gun and bullet will be the same—whether the recoil be large or small; for, the initial pressure being the same, and the degree of expansion, assumed adiabatic in both cases, being determined only by the length of barrel, the pressure-volume diagram for the two cases will be the same.

It is known that the momentum of the bullet will equal that of the gun; for, since Impulse equals Momentum, or

$$f t = m v,$$

and as f and t are the same whether gun or bullet be considered, the product $m v$ must be the same for both. Then, denoting the values for the gun by capital letters, those for the bullet by small letters,

$$M V = m v \text{ or } \frac{W V}{g} = \frac{w v}{g}$$

$$\therefore V = \frac{w v}{W}.$$

The energies are:

$$e = \frac{w v^2}{2 g}$$

$$E = \frac{W V^2}{2 g} = \frac{w^2 v^2}{2 g W}.$$

$$\text{Total energy} = E + e = \frac{w v^2}{2 g}\left(1 + \frac{w}{W}\right)$$

so that the bullet receives the following fraction of the total energy:

$$\frac{e}{e + E} = \frac{W}{W + w}$$

That is to say, as the gun is made heavier or as W increases, the bullet receives an increasing proportion of the total energy of explosion.

Those who find it difficult to follow the above mathematical demonstration may understand the matter by considering what would happen if the gun and the bullet were of the same mass. Evidently in such a case the gun would recoil backward at the same velocity as the bullet is propelled forward. Half the work done by the powder would be expended on the recoil of the gun and half on the propulsion of the bullet. As the weight of the gun increases, however, the proportion of the energy imparted to the gun decreases and when the proportions between projectile and gun reach those used in an ordinary rifle, only a very small part of the work of the powder is lost in producing recoil.

DUPLEX COMPOUND LOCOMOTIVE FOR HEAVY GRADES: NORTHERN RAILWAY OF FRANCE.

The Northern Ry. of France hauls coal and coke from the colliery districts along its line to Paris and other points in fast rains of 950 tons (metric), with four-cylinder compound engines having six coupled driving wheels 5.74 ft. diameter. On one of the most important routes, however, between Lens and Hirson, these engines can haul only 600 tons on the line through Valenciennes (84 miles) or 490 tons on the line through Busigny (91 miles). Both of these lines have long grades of 1 and 1.15%. It was therefore desired to design a special class of engines which, with no greater weight than the regular engines (tender included), could haul the full train load of 950 tons over either of these lines, and would be capable of maintaining average speeds of 30 to 37 miles an hour on the easier portions and exerting great power with lower speeds (11 to 12½ miles an hour) on the heavy grades. These conditions involved relatively large wheels, good stability at speeds as high as 46 to 50 miles an hour, economical operation at both high and low speeds, and high effective power.

The powerful engine designed to meet these conditions had to be carried on six driving axles in order to keep the wheel loads within limits suitable to the track, and as all these could not be motored rigidly in the main frames, it was decided to use the duplex system with the wheels arranged in two groups. In the Mallet duplex system one group of wheels is carried in the engine frame and the other in a steam truck (Engineering News, June 30, 1904); in the Fairlie system the two groups are carried in two independent steam trucks; in the Meyer system two steam trucks are also used, but are connected by a link or knuckle joint, so that as the leading truck swings to or from a radial position it moves the trailing truck also into position. In the new engines the arrangement is practically that of the Fairlie system, but with modifications in detail.

Compounding was adopted, following the practice developed by experience, and to facilitate the steam and exhaust arrangements, the high-pressure cylinders were placed on the rear truck and the low-pressure cylinders on the front truck. The cylinders are placed at the inner ends of their respective truck frames, and in order to avoid too great an overhang an axle with small wheels is placed at the cylinder end of each frame. The engine is thus of the 0 : 6 : 2 : 2 : 6 : 0 type. The tank type of engine was adopted in order to avoid the extra length of a tender (the engine itself being about 53 ft. long over all) and at the same time to make the weight of the fuel and water available for adhesion. The total weight does not exceed 102 tons, while the regular six-coupled engines already mentioned weigh 97 tons with their tenders. The general design of these immense new engines is shown by the sectional elevation and half plan in Fig. 1.

The boiler is very long, with a long Belpaire firebox above the frame; and the boiler, firebox, cab, tanks and coal bunker are all mounted on a single central longitudinal frame of box girder

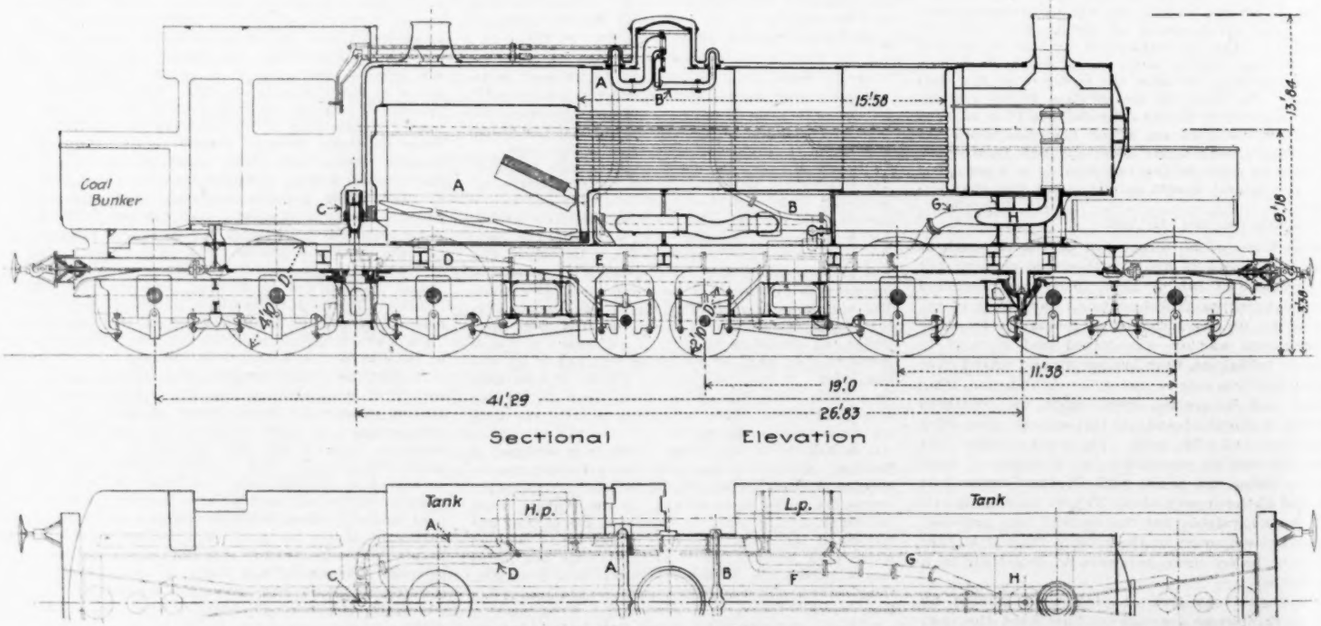


FIG. 1. SECTIONAL ELEVATION AND PLAN OF DUPLEX FOUR-CYLINDER COMPOUND FREIGHT TANK LOCOMOTIVE; NORTHERN RAILWAY OF FRANCE.

construction, as shown by the cross sections in Fig. 2. This girder is 14 ins. deep and 15¾ ins. wide over the cover plates; it extends the full length of the engine and at the ends the webs flare apart, as shown by the plan in Fig. 1. A transverse saddle carries the smokebox, and transverse frames support the boiler barrel, firebox, and bunker. Both trucks are pivoted at their centers. The rear truck has a flat center-plate bearing, and the ends of the two cross

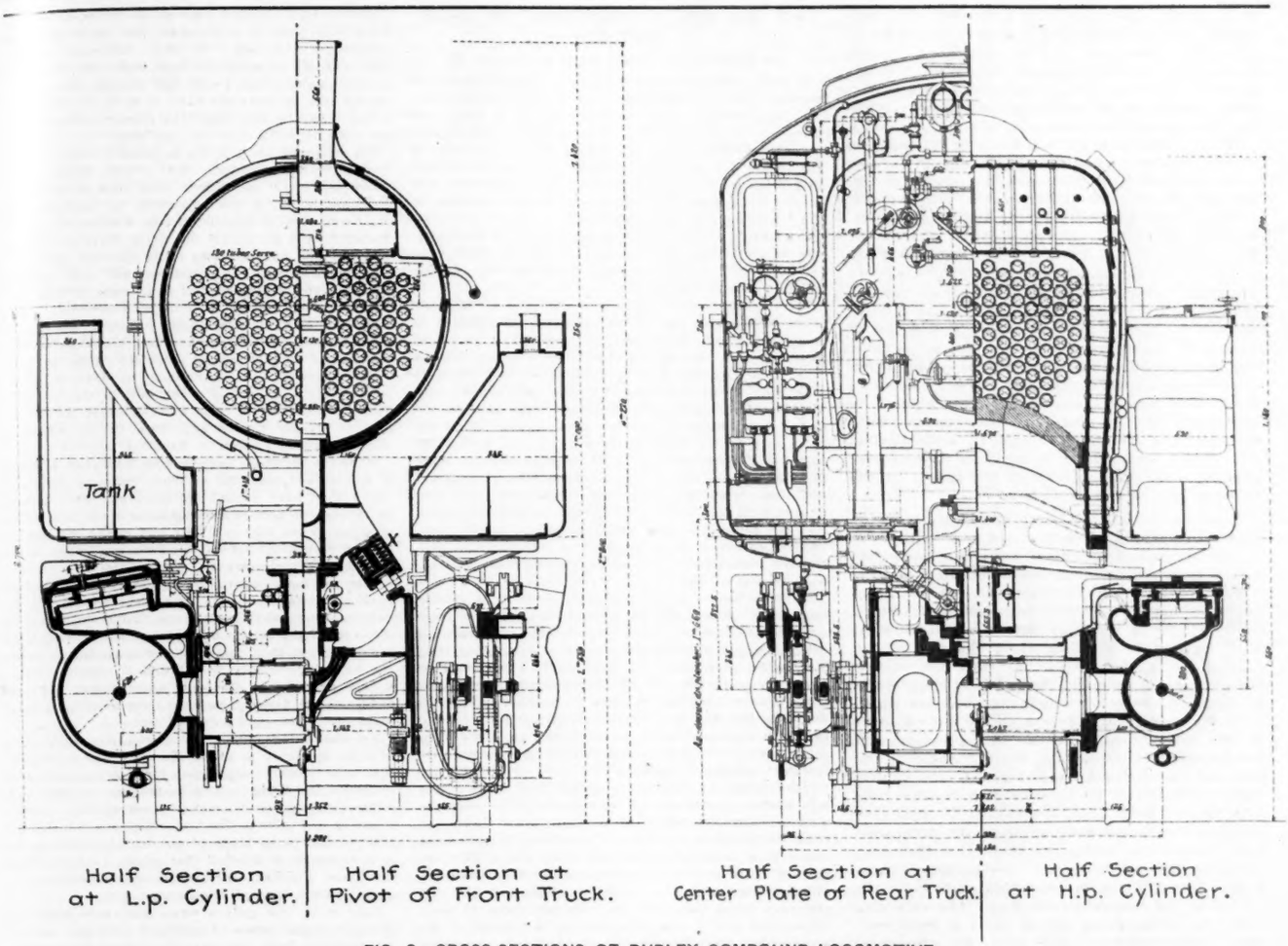

Tank
X
Half Section at L.p. Cylinder.
Half Section at Pivot of Front Truck.
Half Section at Center Plate of Rear Truck.
Half Section at H.p. Cylinder.

FIG. 2. CROSS-SECTIONS OF DUPLEX COMPOUND LOCOMOTIVE.

frames under the back of the firebox and the middle of the cab are supported by four side bearings on the frames of this truck. The front truck, however, must be allowed to tilt laterally on curves independently of the engine and of the rear truck, and for this reason it supports the engine only by a spherical bearing at the pivot, the upper part of the bearing being attached to the saddle under the smokebox. To prevent excessive oscillation of the upper part of the engine, however, two inclined spring buffers are fitted to the sides of the saddle and have plungers seated against the truck frames. One of these is shown at X in the half cross section at pivot bearing, in Fig. 2. The greater part of the water supply (2,378 gallons) is carried in a pair of side tanks on the frames of the front truck, these tanks being of approximately triangular section to allow of lateral movement relatively to the boiler. The remainder of the water (1004 gallons) is carried in tanks on either side of the firebox, and the coal is carried in a rear bunker. The bumper beams, carrying the couplers and spring buffers, are attached to the central longitudinal girder frame. With this arrangement of independent trucks, and with the aid of driving boxes which allow lateral play of the axles, the engine can easily pass curves of 295 ft. radius.

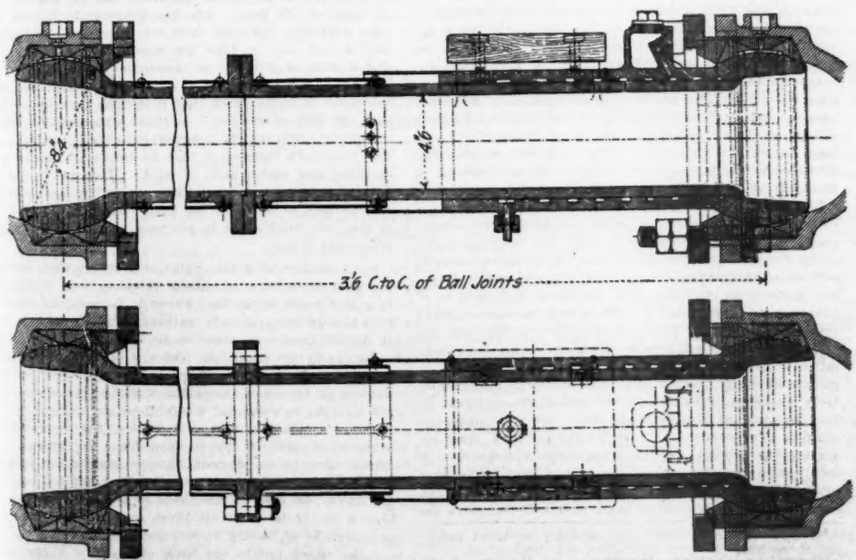


FIG. 3. FLEXIBLE PIPE CONNECTING STEAM CHESTS OF HIGH-PRESSURE AND LOW-PRESSURE CYLINDERS.

The trucks have plate frames, with continuous deck plates on top, and with cast-steel box-girder transoms or bolsters in which are formed the flat center bearing of the rear truck and the spherical center bearing of the front truck. The driving springs are hung below the axle boxes, and those of the two outer axles of each truck are connected by spring equalizers. The inner or carrying axle of each truck has its springs over the boxes and connected to the springs of the inner driving axle by long equalizing beams. The cylinders are outside, with slide valves on top, operated by the Walschaert valve gear. Steel castings are used exclusively. The boiler is of steel, with copper firebox and copper-manganese staybolts. The firebox is of the Belpaire type. The smokebox has a horizontal solid plate diaphragm near the top to prevent the eddying of the hot gases; and below this is the spark arrester diaphragm, 11¼ ins. above the center line of the boiler. The exhaust pipe is very high, and the nozzle opening is made variable by a moving cone; helicoidal wings give a spiral motion to the escaping column of steam. In order to effect a strong connection between the firebox and the boiler barrel, the upper partly of the side plates of the former are extended forward and riveted to the throat connection and the barrel plate. The boiler is fed by two injectors.

The dome is shallow, and contains the main throttle on the steam pipe, A (Fig. 1), to the high-pressure cylinders, and also the throttle of the auxiliary steam pipe, B, to admit live steam to the low-pressure cylinders when necessary. The two steam pipes, A (one on each side of the boiler), are carried back to the center pin of the

rear truck, connecting with a flexible joint consisting of two brass sliding sleeves or tubes, C; from the lower end of this, two pipes, D, run forward to the high-pressure cylinders. The exhaust steam from each of these cylinders is carried forward to the adjacent low-pressure cylinder through a flexible pipe, E (Fig. 3), forming a receiver; the pipe is 4.6 ins. diameter, with a long sleeve joint at one end, and the pipe and sleeve have ball joints in the fixed connections at opposite ends. An intercepting valve, with a piston controlled by compressed air, enables the high-pressure cylinder to exhaust directly into the exhaust pipe of the low-pressure cylinders when the latter are taking live steam. A transverse copper pipe connects the valve chambers of the two low-pressure cylinders; this receives the ends of the flexible auxiliary steam pipes, B, and has at each end a reducing valve set at the reduced cylinder pressure (92 lbs.) allowed when using live steam in these cylinders. Steam escaping from these valves passes through the pipes F to the main exhaust pipes G. Each low-pressure cylinder has an exhaust pipe G, with flexible sleeve and rubber tube connections to a central pipe H, which passes through the saddle to the exhaust pipe in the smokebox.

The reversing gears of both trucks are operated simultaneously by hand or power gear in the cab. A vertical shaft has at its upper end a bevel gear driven by an air motor or a hand-wheel on a horizontal spindle, while at its lower end are bevel gears driving an inclined transverse shaft, which (also by bevel gearing) drives a longitudinal shaft carried in bearings along the side of the central box girder frame. At each end of this shaft are bevel gear and flexible joint connections to threaded shafts on which run the nuts which shift the valve gear. To enable the cut-off to be varied independently in the high-pressure and low-pressure cylinders, the upright shaft in the cab and the inclined shaft below it are double, each consisting of an interior and exterior tube with its own bevel gear; the smaller internal gear operates the longitudinal shaft to the high-pressure valve gear, while the larger annular gear operates the shaft to the low-pressure valve gear. Two pointers on graduated dials show the cut-off in the respective cylinders. The reversing gear, the intercepting valves for the high-pressure direct exhaust, the sand jet apparatus and the cylinder cocks are all operated by compressed air supplied by a small Westinghouse pump in the cab. The air brake is fitted to all the driving wheels.

These engines were designed by Mr. Du Bousquet, Chief Engineer of Motive Power of the Northern Ry., and are described by him in an article in the "Revue Generale des Chemins de Fer," from which we have taken our information. The principal dimensions of these engines are as follows:

Duplex Four-Cylinder Compound Freight Tank Locomotive: Northern Ry. of France.

Driving wheels (12)	4.77 ft.
Carrying wheels (4)	2.78 "
Distance back to back of wheels	4.46 "
Wheelbase, driving (each truck)	11.38 "
Wheelbase of each truck	19.00 "
Distance between carrying axles, c. to c.	3.28 "
Distance between truck centers	26.83 "
Total wheelbase of engine	41.29 "
Total length, over all	53.09 "
Height to center of couplers	3.38 "
Weight on drivers (tanks and bunker empty)	72 tons
Weight of engine, empty	78 "
Weight on drivers, in working order	92 "
Weight of engine, in working order	102 "
Cylinders, HP. (2)	16 × 27.2 ins.
Cinders, LP. (2)	25.2 × 27.2 ins.
Cylinders, distance c. to c.	6.52 ft.
Boiler: type, straight-top; diameter	4.77 "
Barrel plates, thickness	0.6 in.
Height, rail to center line	9.18 ft.
Smokebox, length	5.85 "
Injectors	Two
Steam pressure	227 lbs.
Firebox, copper: type	Belpaire
Length inside	8.0 ft.
Width inside	4.0 ft.
Crown stays	Vertical
Grate bars	Sectional, inclined
Firebrick arch	Yes.
Tubes: Serve ribbed; number	130
Diameter outside	2.8 ins.
Length over tube plates	15.58 ft.
Heating surface: tubes	2,502.34 sq. ft.
Heating surface: firebox	129.01 " "
Heating surface: total	2,631.35 " "
Grate area	32.28 " "
Smokestack, diameter	15.25 ins.
Height above smokebox	26.40 "
Height of top above rail	13.84 ft.
Capacity of tanks (4)	3,382 gallons
Capacity of coal bunker	5 tons

FACT AND IDEA IN ENGINEERING AND ARCHITECTURE.*

By Richard S. Buck,† M. Am. Soc. C. E.

It is a sort of travesty on human intelligence, a sort of paradox, that we must learn how to succeed from failure, that we must learn what we cannot do before we learn what we can do. That there should be such a great disparity between effort and accomplishment, is due to our failure to comprehend, or comprehending, our failure to use the correct relation between Idea and Fact. The Idea is the function that the human mind contributes to the problem of accomplishment; it is a function that has a much broader range of negative than positive values. The Fact is what the laws of nature contribute, and is a fixed quantity. When the two conflict, the idea always cancels out.

Ideas are unquestionably most valuable stock in trade when intelligently directed and properly subordinated to facts, but if you let an idea get the best of you it is worse than a fractious automobile or a strong minded wife. The idea which is of value is the one which is adjustable to all accompanying facts, be they friendly or otherwise. You must always fit your idea to the facts. You cannot fit the facts to your idea. I do not mean to deny the value of ideas which pass beyond the range of demonstrable fact. There is even great value in imagination. Without soaring ideas born of imagination there could be nothing new, no progress; our field of mental action would be narrowed to Archaic limits. But the paramount aim, accompanying a healthy idea, should be to seek the facts governing its object, the real tangible conditions to be met, whether they are what we want to find or not.

In no profession is a proper comprehension or utilization of the correct relation between idea and fact more essential to success than in engineering. Engineering can be fairly defined as the science of discovering facts and the art of using them. Here the fact must be kept constantly in control and the idea subordinate, otherwise there is short shrift for the effort. In other professions the idea has a wider, more independent range—more rope as it were—and in enjoyment thereof can, even when out of harmony with fact, reap success (or apparent success) of considerable duration.

In our kindred profession of architecture, while a certain modest observance of fundamental facts must be maintained, this is deemed by architects a bar sinister on the architectural escutcheon. It is on those rainbow-hued conceptions, those lofty flights of fancy which have expression in beautifully rendered drawings from which all inharmonious accuracy is carefully eliminated, that the architects lavish their devotion. The conversion of these conceptions into accomplishments is, according to the architectural code, the function of "engineers and other mechanics."

Some time ago at a memorable gathering of architects and artists, where a few engineers were invited probably for the purpose of inaugurating a sort of college settlement work among this benighted class, an eminent architect during the course of other enlightening remarks said that it was the proper function of the architect to conceive, design, express, and the proper function of the engineer was to execute what the architect conceived, designed and expressed. This would be a most delightful division of labor—for the architects—were the subordination of idea to fact in the scheme of accomplishment reversed. But there has as yet appeared no sign of such reversal and until it occurs, successful design leading to successful accomplishment will continue to be more dependant upon knowledge of homely facts than upon the training of the Ecole des Beaux Arts, or upon those accomplishments that command the Prix de Rome. Experience must enter into the very first inception of a design, or else, when it appears later, as it inevitably must before the design is converted into an accomplishment, it will have to tear to pieces, patch up, and replace rainbows with sordid earthly material. This is a most painful, a most trying operation.

But while subordination of idea to fact, of imagination to experience, is the fundamental principle of accomplishment, it does not hold that the architecturally trained mind cannot render or has not rendered valuable service in engineering designs. The study of those forms and proportions emerging from the efforts and conflicts of centuries as most fitted to endure and become standard types; the power to build by word and picture for the mind's eye those conditions which are often hopelessly intricate and difficult for the engineer, less versatile in picture drawing; freedom from the deterring influence of facts sometimes distorted to the eye of the engineer in his devotion to materialism; these are the resources wherein the architect is more richly endowed than his engineering brother; but in using them it behooves the architect to keep his feet on the ground, and in constant touch with the facts which engineering experience can alone supply. On the other hand, it equally behooves the engineer, when occasion requires, to lift himself [illegible] the dead level plane of materialism, and he should [illegible] himself to this end. In their differences [illegible] engineer and the architect are both right and both [illegible]rong; and to minimize the wrong and promote the [illegible] they should both cultivate the habit of using the other [illegible] spectacles. Each should study the other's problem [illegible]re—do more studying and less teaching.

The crowning glory of the architect's creed is [illegible]build into utilitarian structures that artistic beauty [illegible]hout which he thinks, not without some show of reason, construction is but a blot cumbering the landscape. But when you seek to establish a rule whereby to judge the beautiful, and go among the living architects to learn, you will find just about as many different rules as you will find architects. No architect will ever agree that the work of another architect is all right until the latter has been long enough dead to be comfortably removed from the field of competition. Nothing enhances the merit of an architect's work among his fellow architects as much as for him to pass peacefully "over the range."

Now engineers are always eager to agree, as we have recently seen so signally exemplified in the case of the Panama Canal, or to come a little nearer home, in the case of Eyebar Chains and Wire Cables, which, like Banquo's ghost, persists in haunting us.

When the architects agree among themselves as to what is correct and beautiful in those forms of construction which they have studied for centuries; when they can go beyond the now narrow limits of stock masonry construction; when they can fully understand the legitimate lines of development of steel and concrete; when they can refrain from cumbering the prime object of a work with a mass of finely drawn ideals and fancies; when they have eliminated from the field more legitimately their own the faults and controversies that crowd there; then they can with propriety *demand* that the material-minded engineer sit at their foot-stool and learn how to beautify his work. Until they do all this it behooves them to handle engineering problems with modest and gentle hands, and to devote themselves more assiduously to self-education in the rigid school of fact.

The controlling principle of engineering works is not to tickle the fancy or please the eye. This is even so of that unfortunately conspicuous form of engineering construction—the bridge. The bridge has serious, sordid, somber business to do, and it is seldom that conditions permit it to do this business with the same pleasing grace that we find in so many of our modern buildings—such as that temple of intellect that graces Longacre Square, the Times Building, or that glorious emporium of dry goods and art, the new Wanamaker store.

Some of us, for quite a while past, have been undergoing an heroic course of treatment in bridge aesthetics. All the way from the carefully studied French art of Hastings and the bold, variegated and versatile conceptions of Hornbostel, down to the highly cultivated ignorance of Montgomery Schuyler and the New York Times and the Calliope chorus of the Municipal Art Society, we have endeavored to absorb and mentally digest. We have been yanked from a school of stern severity, utilitarianism and economy, and translated to an atmosphere of aesthetics filled with colonnades, peristyles, facades, triumphal arches, lofty columns, architectural motives, and skinned-face masonry, where it is a crime to breathe the word economy, and where steel and concrete construction are contemplated with as much abhorrence as a client who objects to the union rate for architectural services of "5 per." We are prayerfully hoping that this strenuous education will not develop mental appendicitis and that in time we may comfortably bear the proud title of "Doctor of Aesthetic Engineering." We are deeply grateful to those who would kindly lead us in the paths of better work, but it is "the back of me hand and the sole of me foot" to those who would drive us.

I do not claim for the engineer individually or as a class that immunity from error that we would all like so much to enjoy and which none of us do. I do not claim that his tribulations and his failures to satisfy are generally due to lack of appreciation from the outside. The rule is that his trouble lies in his own lack of adjustment of ideas and facts.

In these days of great engineering enterprises, demanding bold conception, strenuous thinking, and comprehensive and rapid designing, where it is hard, in adhering to what we have already gathered under our own hats, to do the things we want to do and attract attention to ourselves in the multitude, where it is a wearisome grind to grub for facts often so hard to turn up, where we often have to go for these among the works of rivals whom we are striving to outstrip; where these facts have a nasty habit of conflicting with our desires, the temptation is often irresistible to try to leap from the freshly conceived idea to its accomplishment instead of plodding through the intervening mass of unpleasant but controlling facts. Or else we use those facts that please us and ignore, or try to cover up, those that do not. This dangerous game of fooling oneself and playing that he is fooling the world breaks the neck of many a hardy effort.

The engineer who gets there is the one who can face

*Extracts from a Presidential Address delivered before the Brooklyn Engineers' Club, Dec. 14, 1905.

†Consulting Engineer, Department of Bridges of the City of New York.

arely and without bias in favor of his own mental ucts, all facts favorable and unfavorable and can e his course by a proper balance among them. The ker who fails to do this has to consume much time gray matter constructing explanations why he has succeeded.

We are all more or less disposed to humor and coddle own ideas as we do our own children, and to regard a critical eye or distinct disfavor the other fel-'s ideas as we do the other fellow's children. Many idea is spoiled by too much parental devotion and too clusive an atmosphere. An idea that can grow into mething worth while, can evolve into an accomplish-ent of value, must be capable of enduring strenuous ntact with facts and other ideas. We cannot shape career with our imagination and desires alone.

Accomplishment in engineering to-day is far less the ork of the inspiration of individual genius than it was quarter of a century ago.

Our professional mission to-day is not to strive to im-ress upon the world the capabilities of our minds, nor try to build monuments on which we can write our names in solitary state, but to pick carefully out of the world's vast storehouse of experience those facts best suited to the purpose of our work and to mold patiently and humbly our ideas to them.

We may not thus acquire the fame of the artist or the golden emoluments of the thrifty architect, but we will at least attain some share of success and satisfaction.

CHARGES FOR PRIVATE FIRE PROTECTION.*

At the 1902 convention of the American Water-Works Association a report was adopted, expressing the sentiment of the convention that a charge be made for fire protection; that unreasonably large services for fire or other purposes be not permitted; that meters be used where found necessary, and reasonable control secured of all large services.

The Central States Water-Works Association, at a convention in 1902, unanimously adopted a resolution expressing the sentiment of the convention in favor of an equitable charge for the protection afforded by private fire services.

At the annual convention of 1903, this association adopted a report recommending that a charge be made for fire protection; that unreasonably large services be not permitted; that meters be used where found necessary, and all large services provided with a cut-off or a gate so located as, under any ordinary combination of circumstances, to be readily accessible; action along the same lines as that of the American Water-Works Association for the year previous.

At the 1905 convention of this association, the Fire Pipe Committee was enlarged by the addition of Mr. George W. Batchelder and Mr. Hugh McLane, and instructed to consider and report a method or methods by which the value of fire protection can be estimated.

In compliance with instructions, your committee reports that fire protection should yield a revenue about in proportion to its cost, as compared with the entire cost of the work; that private fire protection may be estimated at some per cent. of the entire cost of fire protection, and apportioned among those benefited in proportion to the floor space of the protected risks. The cost of fire protection, like that of furnishing water, will vary in different localities, as also the proportion properly chargeable to private fire protection, and this may be determined in and for each individual case. Floor space seems to your committee to be the unit bearing the closest relation to value of the risk.

We would recommend that charges for fire protection be made on the above basis, with due regard to different conditions obtaining in different places.

Respectfully submitted: F. H. Crandall, R. J. Thomas, Geo. W. Batchelder, Elbert Wheeler.

DISCUSSION.

Mr. John C. Chase said that he did not think that fire protection in itself should be charged extra, but if a charge is to be levied he thought it could be on a more equitable basis than that proposed by the committee. Mr. Edward V. French, of the Associated Factory Mutual Insurance Cos., said that of late their attention had been devoted more particularly to preventing improper use of water. He thought it would be preferable to charge a certain sum per fire stream *available* since often factories in the same town have really very different pressures and available supplies. Mr. Charles N. Taylor quoted rates which he had drawn up for two places, where charges were based on number of hydrants and sprinkler heads. Mr. J. C. Hammond, Jr., of Rockville, Conn., thought it preferable to base the charge on the amount of insurance carried. The rates charged for private fire protection at Louisville, Ky., and Cleveland, O., were quoted by Mr. H. G. Holden, of Nashua, N. H. After some further discussion, the report was accepted and adopted.

*Report of the Committee on Private Fire Services, New England Water-Works Association, submitted Dec. 13, 1905.

ROTARY KILNS 136 FT. LONG are to be installed in the plant of the Chicago Portland Cement Co., located near La Salle, Ill. The new installation will consist of two new kilns of the length noted and of four old kilns lengthened by an addition to each end. The new kilns will be 7 ft. in diameter for the first 70 ft. of their length. Then will come a tapering section 9 ft. 11 ins. long, reducing the size to 6 ft., and this diameter will be continued for the 56 ft. 1 in. of remaining length. Each kiln will have four riding rings, with steel tires and the necessary driving mechanism. All of this apparatus will be built extra heavy and in proportion to the great length and weight of the kilns. The extensions for the four older kilns will each be 94 ft. long, utilizing 42 ft. of the 6-ft. sections of the present kilns. They will be 7 ft. in diameter for 70 ft., the taper portion will be 9 ft. 11 ins. long and then they will run for 14 ft. 1 in. at 6-ft. diameter until they join the older parts. Each extension will have two riding rings and tires. With one exception these are, we believe, the longest rotary cement kilns ever built; the exception is the plant of the Edison Portland Cement Co., which is equipped with 150-ft. kilns. The new kilns for the Chicago Portland Cement Co. are being built by the Allis-Chalmers Co., of Milwaukee, Wis.

A STANDARD THIRD RAIL or standard position for a third rail contact surface has been suggested by the New York Central & Hudson River R. R. Co., which has initiated a movement to induce the railroads entering New York and Jersey City, to decide upon a uniform standard for third rail location. Without such a standard interchange of rolling stock between different lines in an emergency would be impossible.

A RAILWAY BASCULE BRIDGE on the Strauss system has been built at Cleveland, O., to carry the Wheeling & Lake Erie Ry. across the Cayahoga River. It takes the place of a center-pier swing bridge, and gives a clear waterway of 120 ft. The bascule span has two parallel-chord through trusses 30 ft. deep and having six panels of 24 ft.; the counterweight is a box filled with concrete and slag and weighing about 545 tons; this is supported over the track by pivoted legs, so that when the bridge is open the box almost rests upon the rails. The bridge is operated by electricity, with the main pinion engaging a rack on an inclined operating-strut in the truss. The bridge was built by the American Bridge Co. to the designs of Mr. J. B. Strauss, of Chicago. The latter is the inventor of this particular type of bascule which was described in our issue of Nov. 24, 1904, and the special feature of which is that no-tail-fit is required for the heel of the truss or for the counterweight.

STEAM RAILWAY MOTOR CARS have been built at the Derby shops of the Midland Ry., England, to operate on a line between Antrim and Greenisland on the Belfast & Northern Counties Ry. (Ireland), which is owned by the Midland Ry. This line has the Irish gage of 5 ft. 3 ins. The car is 43 ft. long over the body, with a steel underframe, and the 9-in. channel center sills are extended at the front end to engage with the center bearing on the engine or steam truck. The width of the car is 8 ft. inside, and it has a small baggage compartment at the front end. Next to this are two second-class compartments (smoking, 24 seats, and non-smoking, 16 seats); then a transverse entrance passage or vestible, and a first-class compartment seating six passengers on longitudinal seats. At the rear end is the conductor's compartment. The second-class compartments have a central aisle and cross seats, but the seat backs are not reversible. The steam truck has a small locomotive boiler, and outside cylinders placed between the axles and driving the front axle only; no coupling rods are used. The Walschaert valve gear is employed. The machine was built to the designs of Mr. R. M. Deeley, Locomotive Engineer of the Midland Ry., and Mr. Bowman Malcolm, Locomotive Engineer of the Belfast & Northern Counties line. The principal dimensions are as follows:

Gage of track	5 ft. 3 ins.
Wheels, steam truck, driving (2)	3 " 7¼ "
Wheels, steam truck, trailing (2)	3 " 3 "
Wheels, rear truck (4)	3 " 6 "
Wheelbase, steam truck	10 " 0 "
Wheelbase, rear truck	8 " 0 "
Distance c. to c. of trucks	39 " 7½ "
Length over all	60 " 5½ "
Weight on driving axle	36,034 lbs.
Weight on rear engine axle	21,112 "
Weight on rear truck	30,520 "
Weight, total	87,696 "
Weight, total, empty	79,576 "
Cylinders	9½ × 15 ins.
Boiler, diameter	3 ft. 7½ ins.
Tubes, No., 139; diameter	1¾ "
Tubes, length	4 " 0 "
Heating surface, tubes	262.0 sq. ft.
Heating surface, total	313.0 sq. ft.
Grate area	7.6 sq. ft.
Water	600 U. S. gals.
Coal	1,268 lbs.

THE STEAM RAILWAY MOTOR CARS which are now being extensively used by English railways include some recently built by the London & Northwestern Ry. for branch lines and auxiliary main line service. The underframe is of steel channels and plates, mounted upon a steam truck at one end and an ordinary four-wheel car truck at the other end. The car body encloses the boiler, but this is mounted on the steam truck, and by opening end doors and jacking the body up to clear the center bearing the steam truck can be run out when necessary for repairs, etc. At the front end is the engine room, 12 ft. long, and next to this a baggage room, 4 ft. 6 ins. The two passenger compartments (one being for smokers) are 16 ft. long, separated by a transverse gangway or vestibule, by which they are entered; at the rear end is a small compartment for the engineman when the car is running with the steam truck at the rear. Each passenger compartment has four fixed seats and eight reversible-back seats of the American pattern; there is seating capacity for 48 passengers. Folding steps at the middle vestibule are provided for use at intermediate stops, and are so connected with a brake valve that the vacuum brakes cannot be released until the steps are folded up. The cars have the Consolidated heating system, the Stone electric light system (with dynamo driven from the axle), hand and vacuum brakes, and exhaust ventilators in the roof. Electric bells and speaking tubes afford communication between the two end compartments and the middle vestibule, for the use of the conductor, engineman and fireman, and cords enable the throttle and whistle to be operated from the small end compartment. The steam truck has plate frames with a steel bolster mounted on springs and supporting the body bolster. With this flexible arrangement of the truck bolster the car can pass curves of 165 ft. radius. The cylinders are inside the frames, and between the axles, driving the rear axle; the wheels are connected by coupling rods. The slide valves are operated by the ordinary link motion. The boiler is of the locomotive type. The engines were designed by Mr. George Whale, Chief Mechanical Engineer, and the cars and frames by Mr. C. A. Park, Car Superintendent. The general dimensions are as follows:

Length over body	57 ft. 0 ins.
Length over spring buffers	61 " 0 "
Width, inside	8 " 5 "
Width over all	9 " 0 "
Height, rail to top of frame	4 " 0½ "
Height, rail to top of roof	12 " 5½ "
Height, inside, at middle	8 " 5 "
Height, inside, at sides	6 " 7 "
Driving wheels, diameter	3 " 9 "
Truck wheels	3 " 6 "
Wheelbase, steam truck	8 " 6 "
Wheelbase, trailing truck	8 " 0 "
Wheelbase, total	46 " 0 "
Weight on steam truck	61,376 lbs.
Weight on trailing truck	35,840 lbs.
Weight, total	97,216 lbs.
Cylinders	9½ × 15 ins.
Boiler, diameter	3 ft. 9 ins.
Boiler, rail to center line	7 ft. 11 ins.
Steam pressure	175 lbs.
Firebox, length, 2 ft. 9 ins.; width	3 ft. 6 ins.
Tubes, No. 216; diameter, outside	1¾ ins.
Tubes, length	3 ft. 3 ins.
Heating surface, tubes	275.50 sq. ft.
Heating surface, total	317.27 sq. ft.
Grate area	6.38 sq. ft.
Water tanks (3 on steam truck, 1 on underframe)	546 U. S. gals.
Coal bunkers	1,792 lbs.

PERSONALS.

Mr. E. D. Fletcher has been appointed Chief Engineer of the Tacoma Eastern R. R. Co., succeeding Mr. Henry Shaw.

Mr. E. J. Pearson, Chief Engineer of the Northern Pacific Ry., has recently been appointed Chief Engineer of the Pacific Ry.

Mr. Robert T. Lozier has been appointed District Sales Manager for The Power & Mining Machinery Co., with headquarters at New York City.

Mr. C. F. Dickenson, has resigned his position as vice-President of the Thomas Carlin's Sons Co., Allegheny, Pa. A successor has not been appointed as yet.

Mr. A. W. Richards, Chief of the Export Department of Manning, Maxwell & Moore, leaves soon for three years in Japan, where he will introduce American machinery.

Mr. Edward M. Beake, at one time an assistant engineer on the New York City Subway, will soon open an office in Boston for the general practice of civil engineering.

Mr. William L. Wall and Mr. J. C. Wall, of the San Francisco Engineering Co., San Francisco, Cal., have purchased the entire interest of Mr. William R. Maxwell, the remaining stockholder, and the firm has been dissolved.

Mr. A. T. Benjamin has been appointed Superintendent of the Saratoga and Champlain Divisions, and Mr. D. F. Wait, Superintendent of the Susquehanna Division of the Delaware & Hudson R. R. Co., both with offices at Albany.

Mr. W. L. Darling, Chief Engineer of the Pacific Ry., has been appointed Chief Engineer of the Northern Pacific Ry., with headquarters at St. Paul, Minn. He was formerly Chief Engineer of the Chicago, Rock Island & Pacific Ry.

Mr. Morris Rutherfurd has been elected vice-President and General Manager of the Lehigh & Hudson River Ry.

Co., with offices at Warwick, N. Y. Mr. Rutherfurd will have charge of the Traffic, Transportation and Accounting Departments.

Mr. R. E. Andrews, formerly Chief Engineer of the Casper, South Fork & Eastern R. R., is now Engineer-in-Charge of the work of the Washington Water Power Co., at Postfalls, Idaho. This company is building three dams and a power house.

Mr. Arthur Newhall Johnson, Assoc. M. Am. Soc. C. E., of the U. S. Public Roads Office, and formerly Highway Engineer of the Maryland Geological Survey, has been appointed by the Illinois Highway Commission as State Highway Engineer of Illinois.

Mr. Amos. L. Schaeffer, Assoc. M. Am. Soc. C. E., Senior Assistant Engineer of the Sewer Division of the Rapid Transit Railroad Commission, New York City, has been advanced to the position of Division Engineer, succeeding Mr. Calvin W. Hendrick, resigned.

Mr. Robert P. King has terminated his connection with the Smoke Prevention Department of the city of Indianapolis, and will resume the position of Consulting and Erecting Engineer with the firm of Brossmann & King, Lemcke Building, Indianapolis, Ind.

Mr. Henry S. Pritchett, for five years President of the Massachusetts Institute of Technology, has resigned his position in order to devote his entire time to his new position as President of the Carnegie Foundation Fund for pensioning of aged and needy professors.

Mr. Wm. T. Blunt, M. Am. Soc. C. E., who has been in government service a greater part of the time since 1879, has been given an indefinite furlough, and will enter contract work with Geo. H. Breymann & Bros., at Boston. Mr. Blunt has been Assistant Engineer upon the Cleveland District harbor works since 1886.

Mr. Verne L. Havens, Jun. Am. Soc. C. E., has resigned his position as Principal Assistant Engineer of the Tri-State Land Company Canal of Scotts Bluff, Neb., and has accepted a position as Assistant Engineer with the Mexican Light & Power Co., of Necaxa, Puebla, Mex. Mr. T. M. Donelson succeeds Mr. Havens as Engineer in charge of construction at Scotts Bluff.

Mr. H. H. Vaughan, Superintendent of Motive Power of the Canadian Pacific Ry., has recently been advanced to the position of Assistant to the vice-President of this road. This new position will give him jurisdiction over motive power, rolling stock, stores, fuel and all electrical and mechanical matters. The placing of motive power and rolling stock matters in the hands of an executive, who is not a department official, is a departure from general railway custom. Mr. Vaughan is an exceedingly young man for his present responsibilities. Since coming to this country from England in 1891 and entering the shops of the Great Northern Ry. as a machinist, his advancement has been rapid. In 1895 he became Mechanical Engineer for this company, and while acting in this capacity designed the present engineer's valve of the New York Air Brake Co. He has occupied successively the following positions: Mechanical Engineer of the Philadelphia & Reading R. R., Manager of Shops and Engineering Department of the Queen & Crescent Route, Assistant Superintendent of Motive Power of the Lake Shore & Michigan Southern Ry., and the position he is just leaving.

Obituary.

J. H. Serviss, prominent among the civil engineers of northern New Jersey, died recently in his home at Closter, N. J. Mr. Serviss graduated from Union College in 1863.

T. A. Bennett, a mining engineer of high reputation, died at Lima, Peru, on Nov. 23. Mr. Bennett was associated with the Exploration Co., of London, in a copper mining enterprise in Peru.

Winfield Scott De Hart, vice-President of the Colonial Construction Co., New York City, died suddenly Dec. 14 of pneumonia at the Hotel St. James, where he resided with his wife. Mr. De Hart was 54 years old.

Carl G. Seligman, a civil engineer employed by the Delaware, Lackawanna & Western R. R., died of pneumonia Dec. 10 aboard the Scandinavian American steamship "United States." He was 47 years old, and lived in Hoboken.

Leroy H. Anderson, of Princeton, N. J., died of heart disease Dec. 15. Mr. Anderson was at one time Assistant Treasurer of the Delaware & Raritan Canal Co., and later became Treasurer of the United Railroads of New Jersey. He was a member of the class of '61 of Princeton University and was also its permanent secretary.

William H. Shock, Engineer-in-Chief, United States Navy, retired, died Dec. 17 at his home in Washington after a brief illness. Commodore Shock was 84 years old and therefore one of the oldest officers on the naval list. He was a veteran of the Mexican and Civil Wars and served under Commodore Perry and Admiral Farragut.

Capt. Samuel S. Brown, one of the prominent business men and manufacturers of Pittsburg, died at his home, Brown's Station, near Pittsburg, Dec. 11. Capt. Brown was the president and principal owner in the Homestead & Pittsburg Bridge Co., director in the Monongahela River Consolidated Coal & Coke Co., as well as being connected with many other enterprises.

Gen. Herman Haupt, one of the oldest civil engineers in the United States, died suddenly, on Dec. 14, on a Pennsylvania Railroad train leaving Jersey City for Washington. He was accompanied at the time by his son, Prof. Lewis M. Haupt, formerly a member of both the Nicaraguan and the Panama Canal Commissions. No cause, other than advanced age, is assigned for his death. Gen. Haupt was born in Philadelphia March 26, 1817. He was graduated from the Military Academy at West Point in 1835, but he resigned in October of the same year to enter upon the practice of civil engineering. In 1844-47 he was Professor of Civil Engineering in the Pennsylvania College. He was then for a time Chief Engineer of the Pennsylvania R. R., and for a long time Engineer of the famous Hoosac Tunnel, in Massachusetts. At the outbreak of the Civil War he entered the Northern Army, and successively became Colonel, Brigadier General and Chief of the Bureau of U. S. Military Railways, performing much valuable service in this latter connection. After the war he became General Manager of the Piedmont Air Line Railway, Engineer of the Tide Water Pipe Line and General Manager of the Northern Pacific Railway. Gen. Haupt was one of the first among American engineers to discuss the theory of stresses in framed structures, and he published in 1852 his "General Theory of Bridges." Among his other publications, in addition to his professional reports and papers, are, "Military Bridges," 1863; "City and Suburban Motors," 1893, and "Reminiscences of Gen. Herman Haupt," 1902. He had resided in Washington, D. C., for a number of years.

ENGINEERING SOCIETIES.

COMING MEETINGS.

AMERICAN ECONOMIC ASSOCIATION.
Dec. 27 to 29. Annual meeting at Baltimore, Md. Secy., F. A. Fetter, Ithaca, N. Y.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
Dec. 29 to Jan. 4. Annual meeting at New Orleans, La. Secy., L. O. Howard, Washington, D. C. Secy. of Section D (Mechanical Science and Engineering), Prof. W. T. Magruder, Columbus, O.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.
Jan. 4, 1906. Annual meeting at Pittsburg, Pa. Secy., F. V. McMullin, 410 Penn Ave., Pittsburg, Pa.

MICHIGAN ENGINEERING SOCIETY.
Jan. 9, 10, 1906. Annual convention at Lansing, Mich. Secy., F. Hodgman, Climax, Mich.

NATIONAL ASSOCIATION OF CEMENT USERS.
Jan. 9 to 12, 1906. Annual convention at Milwaukee, Wis. Secy., C. C. Brown, Commercial Club Bldg., Indianapolis, Ind.

NEW ENGLAND WATER-WORKS ASSOCIATION.
Jan. 10. Annual meeting at Boston, Mass. Secy., Willard Kent, Narragansett Pier R. I.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
Jan. 17 and 18. Annual meeting at the Society House, 220 West 57th St., New York City. Secretary, C. W. Hunt, address as above.

NORTHWESTERN CEMENT PRODUCTS' ASSOCIATION.
Jan. 17, 18, 19. Annual convention at Minneapolis, Minn. Secy., F. H. Chapin, 10 N. Third St., Minneapolis, Minn.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS.
Jan. 17, 18, 19. Annual meeting at Rockford, Ill. Secy., E. E. R. Tratman, 1636 Monadnock Block, Chicago.

INDIANA ENGINEERING SOCIETY.
Jan. 18, 19, 20. Annual meeting at Indianapolis, Ind. Secy., C. C. Brown, Commercial Club Building, Indianapolis, Ind.

AMERICAN INSTITUTE OF MINING ENGINEERS.
Feb. 21. Annual meeting at South Bethlehem, Pa. Secy., R. W. Raymond, 99 John St., New York, N. Y.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.—Two papers on rotary converter substations were presented at the December meeting, held at 44 West 27th St., New York, on the evening of Dec. 15. These were: "The Relation of Railway Substation Design to Its (?) Operation," by S. W. Ashe, and "Some Considerations Determining the Location of Electric Railway Substations," by C. W. Ricker. The first paper, while it mentioned many items of design, dealt mainly with provisions for starting converters; these were listed as starting from the A. C. side, starting on direct current either from direct-current bus-bars or from a special shunt-wound generator, and starting by a small direct-connected induction motor. The paper attributed about equal degrees of importance to these three methods, but in discussion it appeared that starting by alternating current is suited to more varied conditions than the other methods. The second paper outlined in condensed form a method of procedure for determining the most suitable point of location, or most suitable spacing, of railway substations, in those cases where there is a broad range of choice. The method consists in drawing curves, plotted from a few points, to represent the variable elements of yearly cost, that is, those elements which are dependent upon number or spacing of substations, after first eliminating, by careful analysis, those items of yearly cost which should not vary with substation distance.

BROOKLYN ENGINEERS' CLUB.—The annual dinner of the Brooklyn Engineers' Club was held in the hall of the Oxford Club, Brooklyn, New York City, on the evening of Thursday, Dec. 14. According to custom the annual election of officers was conducted on the same evening. The following were elected: President, Mr. S. Tuttle; Treasurer, Mr. John Middleton; Secretary, Mr. Joseph Strachen; Directors, Messrs. L. J. Carmalt and K. L. Martin.

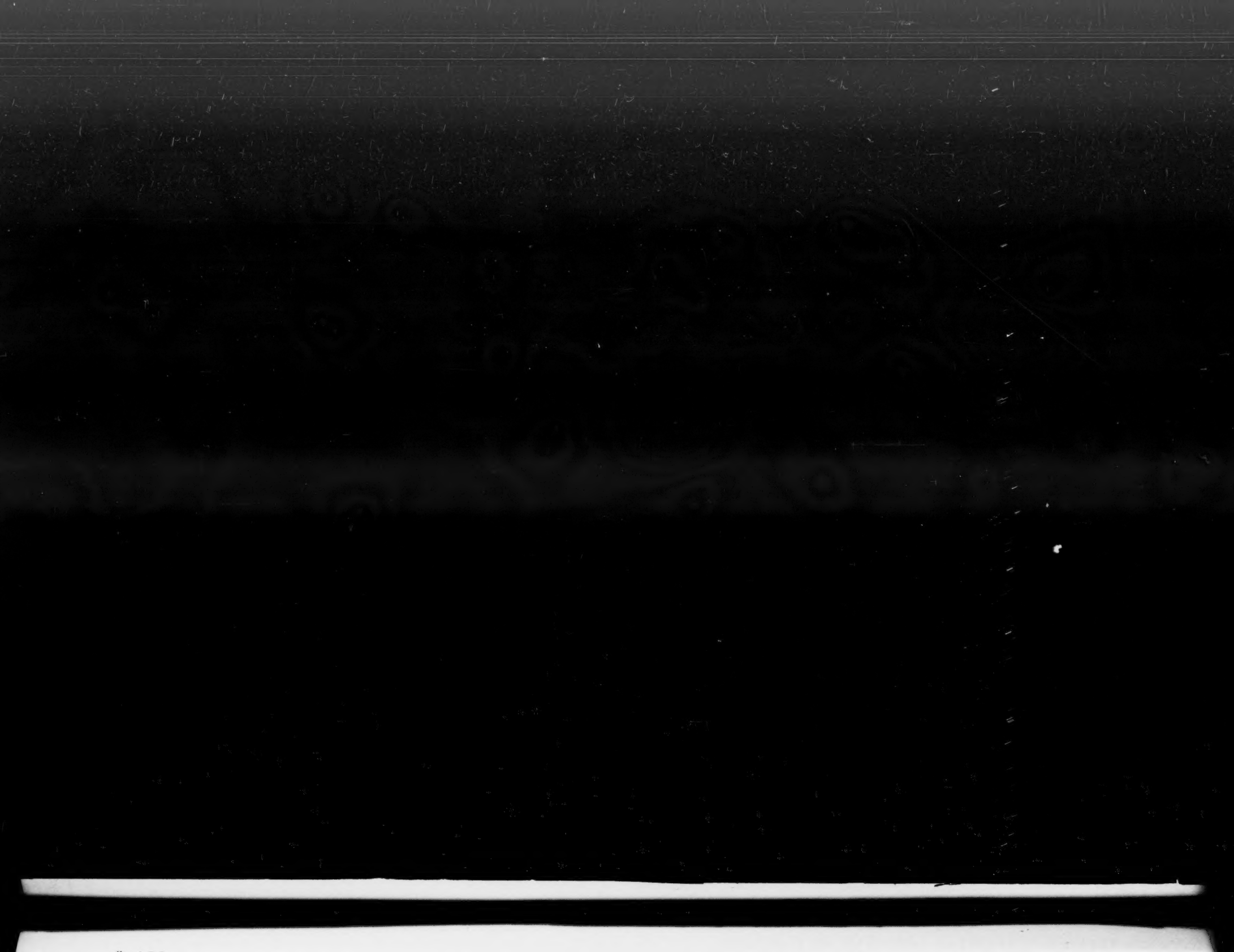
The dinner drew a very large attendance, and was thoroughly successful. Humorous and serious addresses by Mr. W. H. Boardman, ex-Congressman E. M. Bassett, Mr. Henry Hornbostel, Mr. H. H. Howe, and Retiring President R. S. Buck, formed an enjoyable supplement to the more essential part of the dinner. Mr. Buck's address, reprinted on another page of this issue, contained a timely protest against the common attitude of the architectural profession towards engineering. Mr. Boardman was equally bold in his address, for he advocated nothing less than an elimination of the laboratory and the imitation shop from technical instruction. The acme of iconoclasm was reached by Mr. Bassett, who, in a very brief review of the Panama Canal project, managed to exhibit a very pessimistic impression concerning the wisdom or distinterestedness of those who were directly responsible for the present state of canal affairs. He admitted, however, that the country is now committed to the Panama scheme, and that the movement cannot be stopped.

NEW ENGLAND WATER-WORKS ASSOCIATION.—A meeting was held in Boston on Wednesday, Dec. 13, 1905, which proved very interesting, all of the three subjects considered eliciting considerable discussion. The only formal paper was by Mr. Alfred O. Doane, Division Engineer of the Metropolitan Water-Works, on "Pressure Regulators." An abstract of this paper and the discussion on it will be printed in a later issue.

The committee on private fire services reported, in accordance with instructions, a scheme for assessing rates against such services. The report and a resumé of the discussion upon it may be found elsewhere in this issue.

A topical discussion on the subject of electrolysis was opened by Mr. E. C. Brooks, of Cambridge, who had brought in a section of 6-in. pipe containing many pittings, besides two considerable holes. This illustrated very well the manner in which electrolysis attacks such a pipe, and also showed that in many cases a superficial examination would not indicate that injury existed, although the pipe might be very badly pitted. Mr. Brooks also described the injury to the 40-in. steel supply main forming part of the Cambridge water-works, and stated that he had had some pipes give out under telephone cables. Mr. Wm. E. Foss, Division Engineer of the Metropolitan Water-Works, spoke more particularly of the difficulty of detecting injury to cast-iron pipes except by testing with a point, although damage to wrought iron or lead is obvious. Attempts to prevent electrolysis by bonding water pipes to rails have not been successful, as they result in making the pipes a part of the railroad return. As much as 3,000 amperes have been found flowing in a 12-in. gas pipe, making the pipe perceptibly warm. To absolutely prevent injury it would be necessary to make every structure negative to every other, which is impossible; the next thing is to make each one neutral to every other, which is impracticable. In England the law requires that the maximum difference of potential between any two structures shall not exceed seven volts, and they have had very little trouble from electrolysis. Such a regulation in this country, if fulfilled, would remove from 60 to 90% of the trouble.

Insulating joints of two types have been tried upon the Metropolitan Water-Works: one made by inserting a wooden ring in the bottom of the bell and completing the joint in the ordinary bell and spigot pipe with wooden wedges; the other being a flanged joint with a rubber gasket and insulated bolts. They have been about equally successful. They result in greater differences in potential on the two sides of the joint, and a large reduction of the amount of current flowing at that point. When dry the resistance of either type is several hundred thousand ohms; but it drops to 100 to 200 ohms when the pipe is filled with water, and in service in the earth it soon falls to only a few ohms. Several insulating coatings have been tried, all of which proved failures.

Mr. John A. Gould, of the Boston Gas Co., said that gas pipes were never so badly troubled as water pipes, partly because gas has no conductivity, and partly, perhaps, because of the large number of cement joints used. One main, however, lasted only five or six years. The troubles in Boston are decreasing. One gas main was laid with a rubber gasket at each joint, and has given no trouble up to this time. He thought there was no positive remedy until the street railways adopted the alternating current, which does not cause electrolysis.

Several other members took part in the discussion, and samples of service pipes perforated by electrolysis were shown.